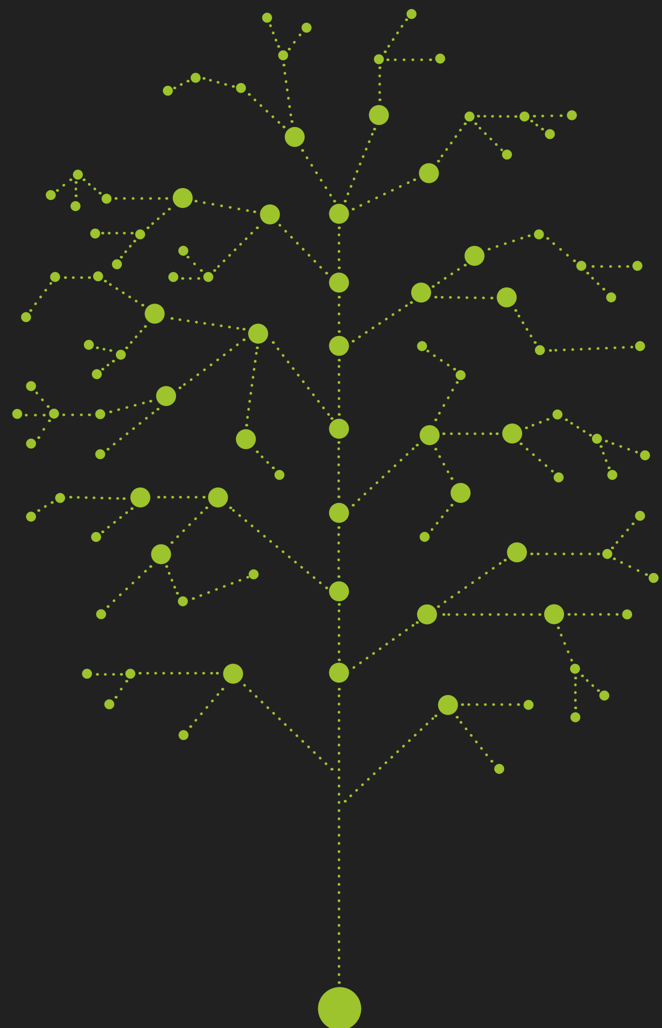

# environmental engineering

## Building Installations


edited by
Jarosław Müller
Joanna Bąk



Cracow University of Technology

Kraków 2020

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This text was published as a part of the project 'Excellence programming – PK XXI 2.0 Cracow University of Technology Development Program for the years 2018–2022'.

Funding from EU: 18,048,774.96 PLN


eISBN 978-83-66531-29-1
Online edition
16 publisher's sheets

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European Funds
Knowledge Education Development

Republic of Poland

European Union
European Social Fund

# Table of Contents

# Part 1

## *Ventilation systems: natural ventilation*

*Jarosław Müller*

# OUTLINE OF THIS PART:

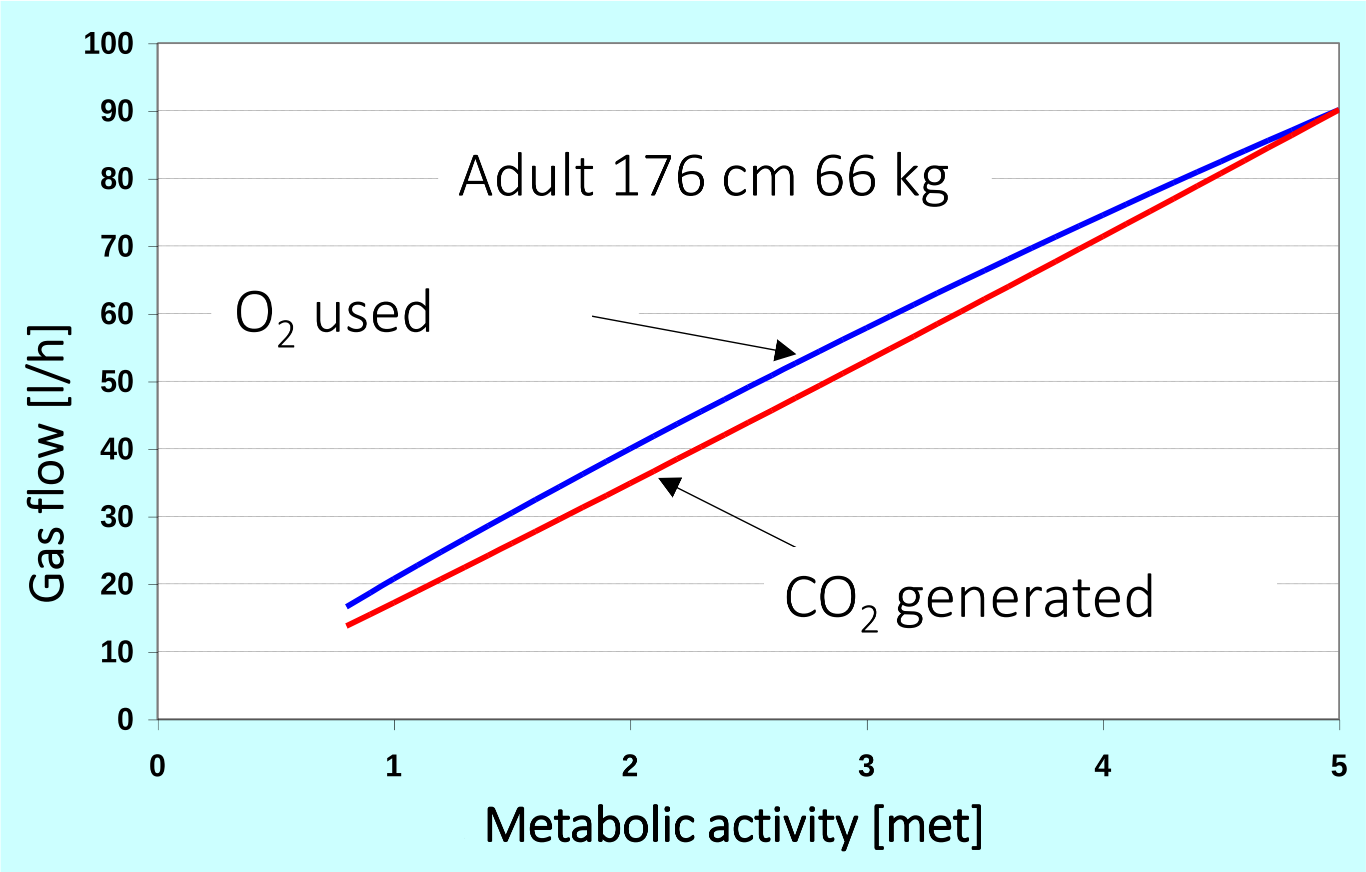
- Definition
- $CO_2$
- Comfort
- Natural ventilation
- Support

# Room ventilation

The system replacing the air in a room or its part that is designed to remove waste and polluted air and introduce outside air.

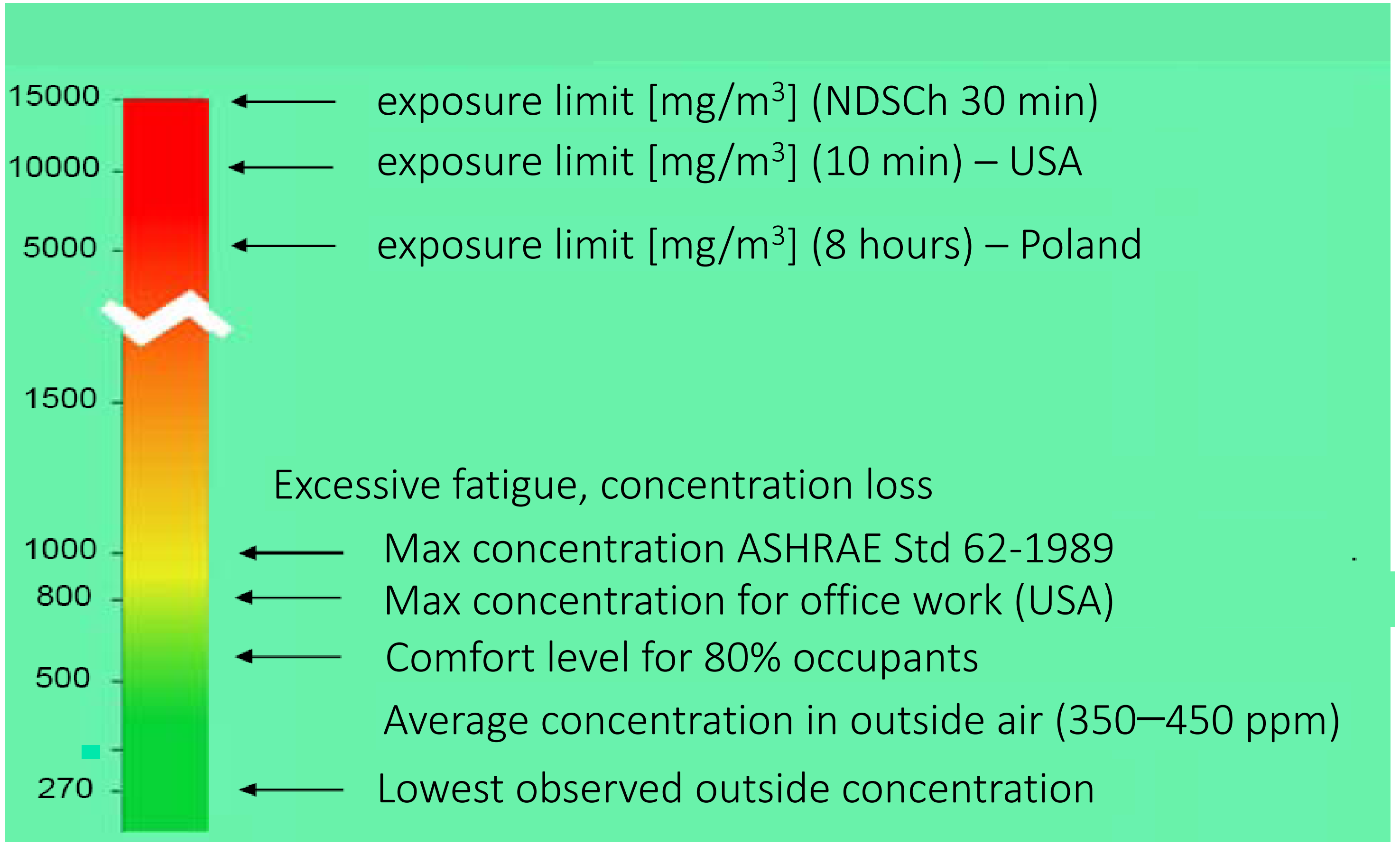
Ventilation is a process of **structured** exchange of air in the room.

# $CO_2/O_2$ balance




2.500 l of air per day

# $CO_2$ concentration




*Source: Gazex bulletin W17, 2003*

# Effects of bad ventilation

- $CO_2$ concentration increase
- The risk of water condensation
- The risk of CO poisoning
- Sick building syndrome (SBS)
- SBS symptoms

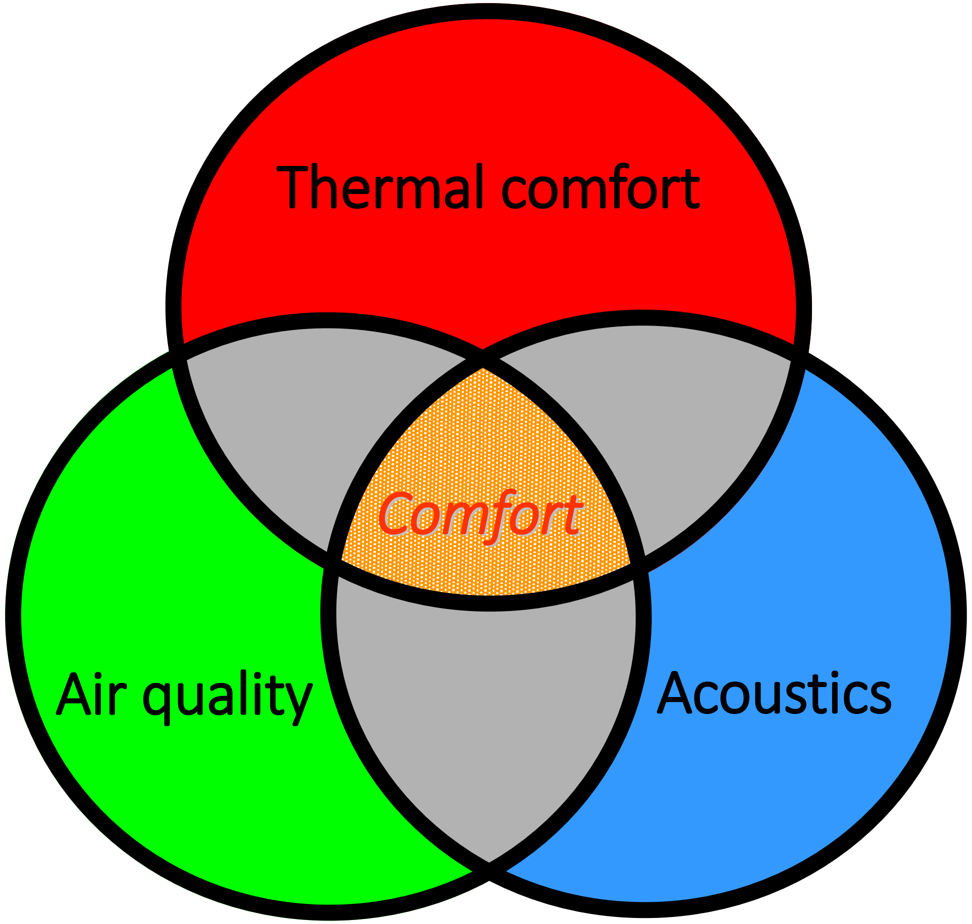
Headaches and dizziness, excessive fatigue, nausea, skin rash, trouble with concentration, in some cases even fainting.

# SBS – Sick Building Syndrome

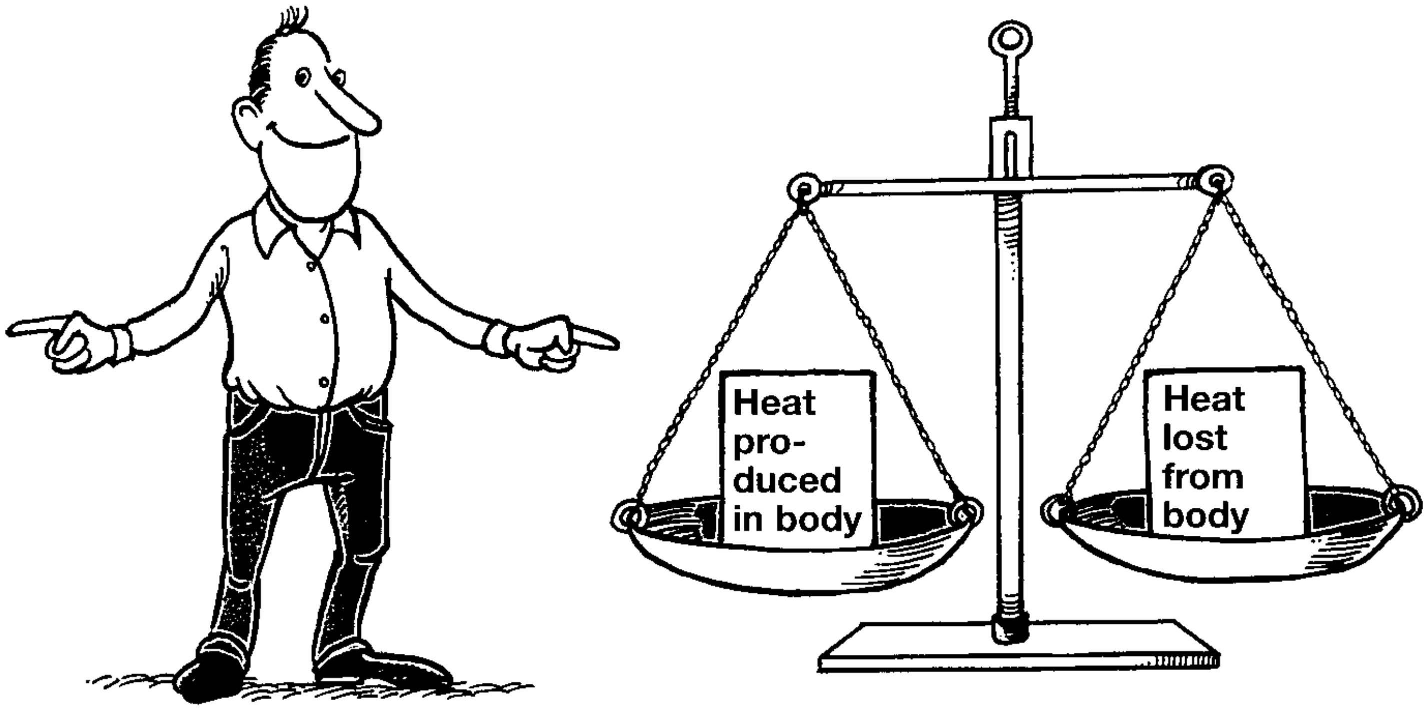
Ailments associated with SBS and breathing contaminated air:

- fatigue, or performance degradation
- irritability, or interpersonal conflicts
- shortness of breath, or frequent work-breaks
- headaches and dizziness, or frequent visits to doctors
- lowered concentration, or considerable workplace errors
- fainting, or break in work and medical absence
- respiratory problems, or considerable hospitalizations and sicknesses
- allergies, or sickness and absences
- being easily infected with, for example, influenza, or mass sicknesses

# Room comfort



# Heat balance = thermal comfort



# Public buildings minimum ventilation air flows (by PN-83/B-03430/Az:3 2000)

If the windows **can** be open:

Areas for permanent and temporary stay of people should be given a supply of at least 20 $m^3/h$ outside air for each person.

If the windows **cannot** be open:

Areas for permanent and temporary stay of people should be given a supply of at least 30 $m^3/h$ outside air for each person.

# Indoor air classification (by: EN 13779)

Minimum flow of fresh air in rooms intended for permanent human presence

| Category | Unit | Rate of outdoor air per person | | | |
|---|---|---|---|---|---|
| | | Non-smoking area | | Smoking area | |
| | | Typical range | Default value | Typical range | Default value |
| **IDA 1** (WEW 1) | $m^3$ / (h*pers)<br>$l \cdot s^{-1} \cdot (pers)^{-1}$ | > 54<br>> 15 | 72<br>**20** | > 108<br>> 30 | 144<br>40 |
| **IDA 2** (WEW 2) | $m^3$/(h*pers)<br>$l \cdot s^{-1} \cdot (pers)^{-1}$ | 36–54<br>10–15 | 45<br>**12.5** | 72–108<br>20–30 | 90<br>25 |
| **IDA 3** (WEW 3) | $m^3$/(h-*pers)<br>$l \cdot s^{-1} \cdot (pers)^{-1}$ | 22–36<br>6–10 | 29<br>**8** | 43–72<br>12–20 | 58<br>16 |
| **IDA 4** (WEW 4) | $m^3$/(h*pers)<br>$l \cdot s^{-1} \cdot (pers)^{-1}$ | < 22<br>< 6 | 18<br>**5** | < 43<br>< 12 | 36<br>10 |

# Standard air flows (PN-83/B-03430)

| Type of room | Air flow [$m^3/h$] |
|---|---|
| Kitchen with window (gas stove) | 70 |
| Kitchen with window (electric stove) | 30–50 |
| Kitchen without window (electric stove) | 50 |
| Kitchen without window (gas or coal stove) | 70 |
| Bathroom with WC or without one | 50 |
| Separate WC | 30 |
| Windowless room | 15 |
| Living room separated from the kitchen, bathroom and WC by more than 2 doors | 30 |

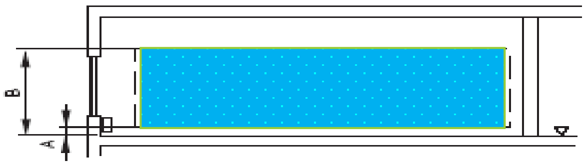
# Examples (PN-83/B-03430)

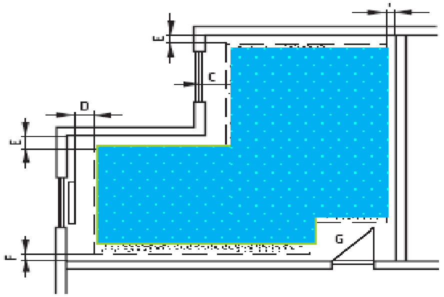
| | |
|---|---|
| Apartment type A | 120 $m^3/h$ |
| Apartment type B | 150 $m^3/h$ |
| Apartment type C | 165 $m^3/h$ |

Type A: bathroom and WC in one
Type B: bathroom separated from WC
Type C: bathroom separated from WC plus windowless room

# Occupied zone (by: EN 13779)

| Distance from the inner surface of: | | Typical range [m] | Default value [m] |
|---|---|---|---|
| Floors (lower boundary) | A | 0.00–0.20 | 0.05 |
| Floors (upper boundary) | B | 1.30–2.00 | 1.80 |
| External windows and doors | C | 0.50–1.50 | 1.00 |
| HVAC appliances | D | 0.50–1.50 | 1.00 |
| External walls | E | 0.15–0.75 | 0.50 |
| Internal walls | F | 0.15–0.75 | 0.50 |
| Doors. transit zones etc. | G | Special agreement | |





# Air flow for reducing the gas pollution concentration [m$^3$/s]

$$\dot{V}_s = \frac{Z\phi}{c_{IDA} - c_{SUP}}$$

where:

$Z$ – flow of contaminating gas [g/s]

$\phi$ – factor taking into account the uneven spread of pollutants in the room

$c_{IDA}$ – allowable concentration of the pollutants in the air [g/m$^3$]

$c_{SUP}$ – concentration of the pollutants in the supply air [g/m$^3$]

# Air flow calculated based on moisture gains [m³/h]

$$\dot{V} = \frac{3600 * W_s}{\rho(x_{EHA} - x_{SUP})}$$

where:

$W_s$ – water vapor gains [kg/s]

$\rho$ – air density [kg/m³]

$x_{EHA}$ – moisture content in the exhaust air [kg/kg]

$x_{SUP}$ – moisture content in the supply air [kg/kg]

# Air flow to prevent the temperature rise in the zone [m$^3$/h]

$$V = 3600 \frac{\Phi_j}{c_p \rho (\theta_{IDA} - \theta_{SUP})}$$

where:

$\Phi_j$ – total sensible heat gains [kW]
$c_p$ – specific heat of moist air [kJ/kgK]
$\rho$ – air density [kg/m$^3$]
$\theta_{IDA}$ – maximum temperature in the occupied zone [°C]
$\theta_{SUP}$ – temperature of supply air [°C]

# Ventilation effectiveness (by: EN 13779)

$$\varepsilon_v = \frac{c_{EHA} - c_{SUP}}{c_{IDA} - c_{SUP}}$$

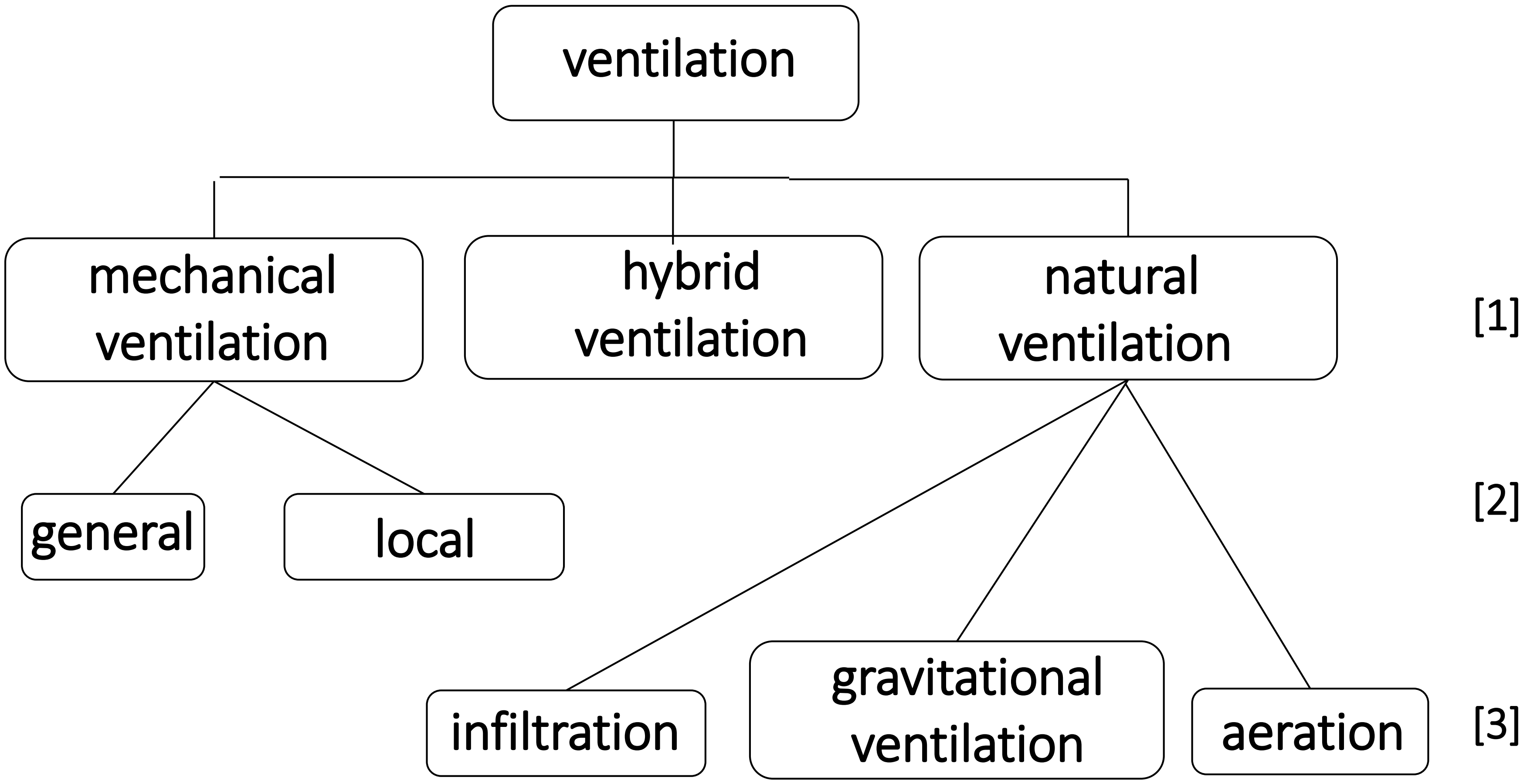
where:

$\varepsilon_v$ – ventilation effectiveness

$c_{EHA}$ – pollution concentration in the exhaust air

$c_{IDA}$ – pollution concentration in the indoor air (breathing zone within the occupied zone)

$c_{SUP}$ – pollution concentration in the supply air




[1] energy moving the air
[2] ventilated space
[3] causes of natural ventilation

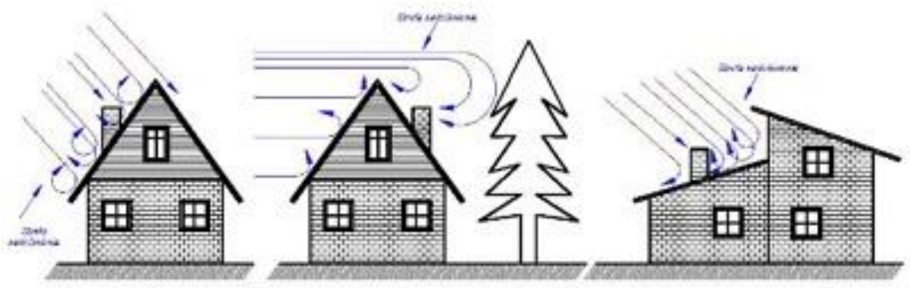
# Natural ventilation

– is caused by temperature and pressure difference between the inside and the outside

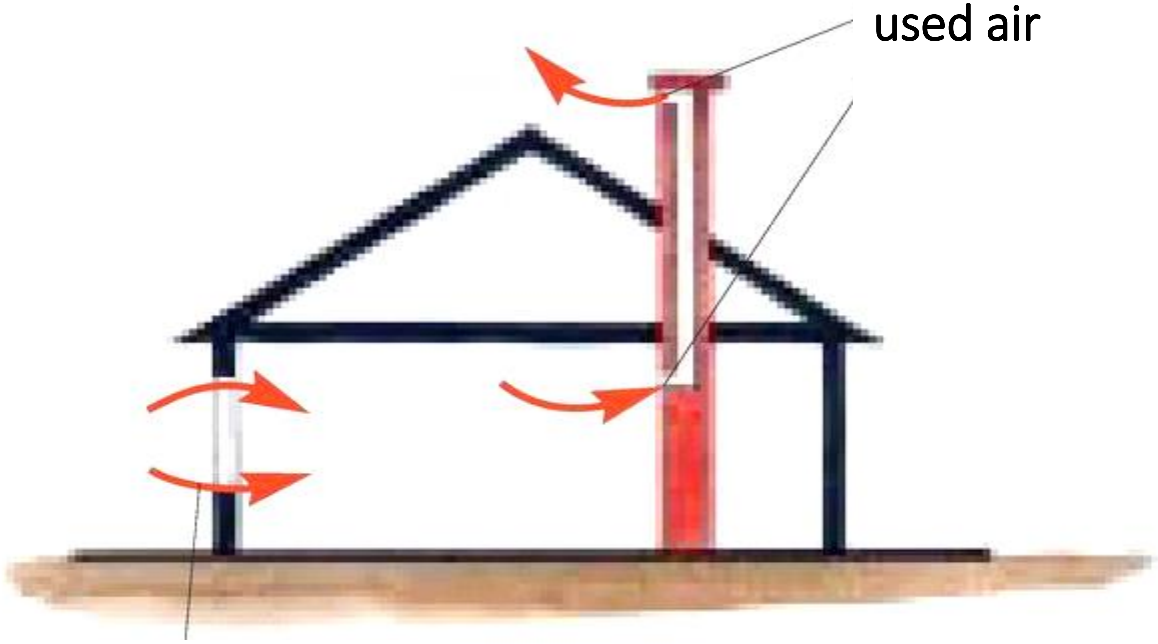
- **Infiltration** – Self-exchange of air through leaks in doors and windows and the building envelope.
- **Gravitational ventilation** – natural ventilation caused by temperature difference between the inside and the outside
- **Aeration** – natural ventilation organized through the openings connecting the zone with the ambient caused by temperature and pressure difference
- **Mechanical ventilation** – ventilation caused by the work of fans
- **General ventilation** – ventilation of the whole zone
- **Local ventilation** – ventilation of specified area within the zone (working place, machine etc.)

# Natural ventilation

- The least investment cost
- Very quiet, no need for driving energy
- Highly dependent on thermal outside and inside conditions
- May cause the highest running costs
- Highly dependent on air tightness of zones and windows
- Virtually uncontrolled
- Dependent on the shape of the roof, neighbouring buildings, trees
- Requires support
- May be the reason of draughts
- Needs to be inspected



# The principle of natural ventilation




**In single – family houses gravitational ventilation is the most common**

Lighter air is being displaced by colder, denser air. In cold seasons used air is removed through the exhaust grilles in the kitchen, WC or bathroom. The outside (fresh) air enters through the openings in doors or windows.

# Causes of inadequate natural ventilation

- Weather conditions
- Obstructed ducts (chimney – sweeps)
- Air-tight windows, the lack of openings
- Air tight inner doors

# Gravity effect

$$\Delta p_g = h_g \cdot g \cdot (\rho_z - \rho_w)$$

where:
$h_g$ – distance between vent opening and neutral plane [m]
$g$ – gravity [m/s$^2$]
$\rho_z$ – air density at outside temperature [kg/m$^3$]
$\rho_w$ – air density at inside temperature [kg/m$^3$]

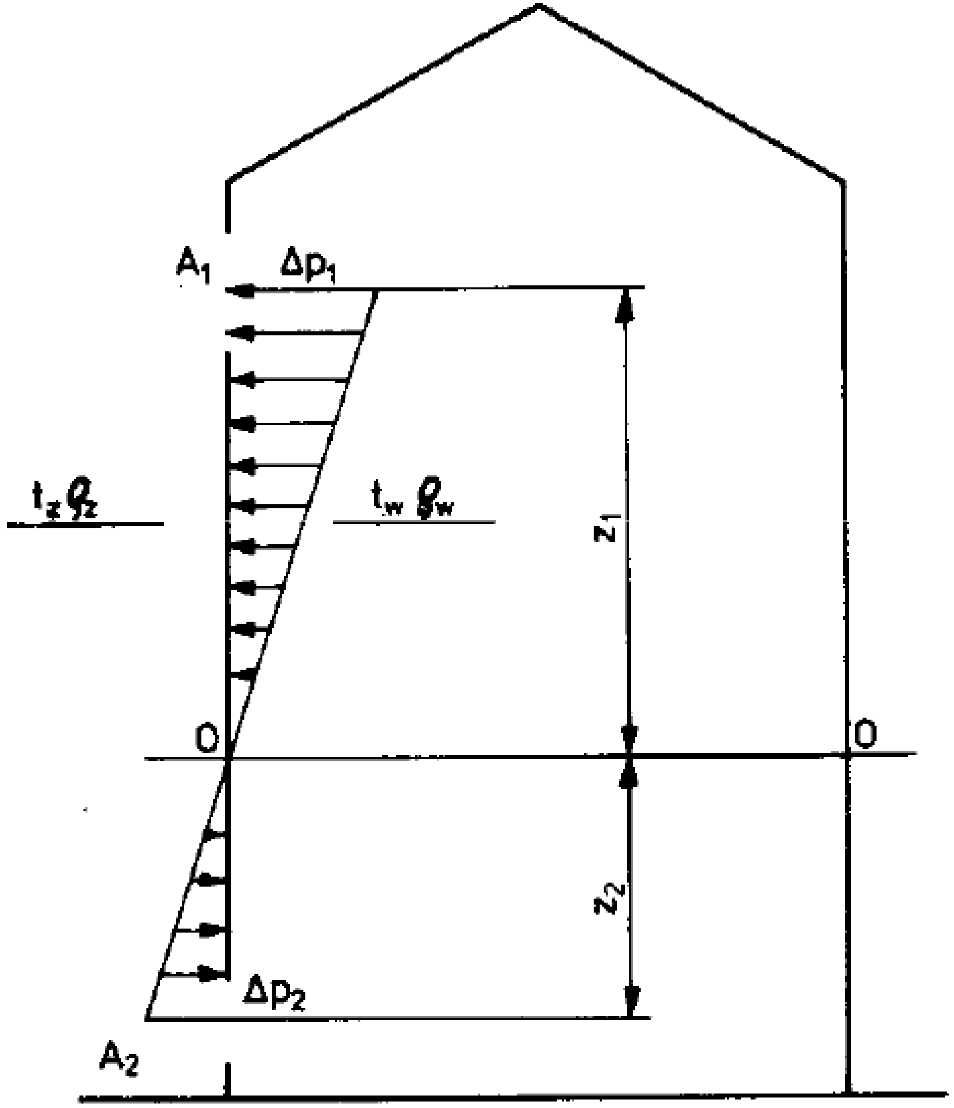
Example
A stack 10 m high, outside 0°C, inside 30°C

$$\Delta p_g = 10 \cdot 9.81 \cdot (1.2927 - 1.1644) = 12 \text{ Pa}$$

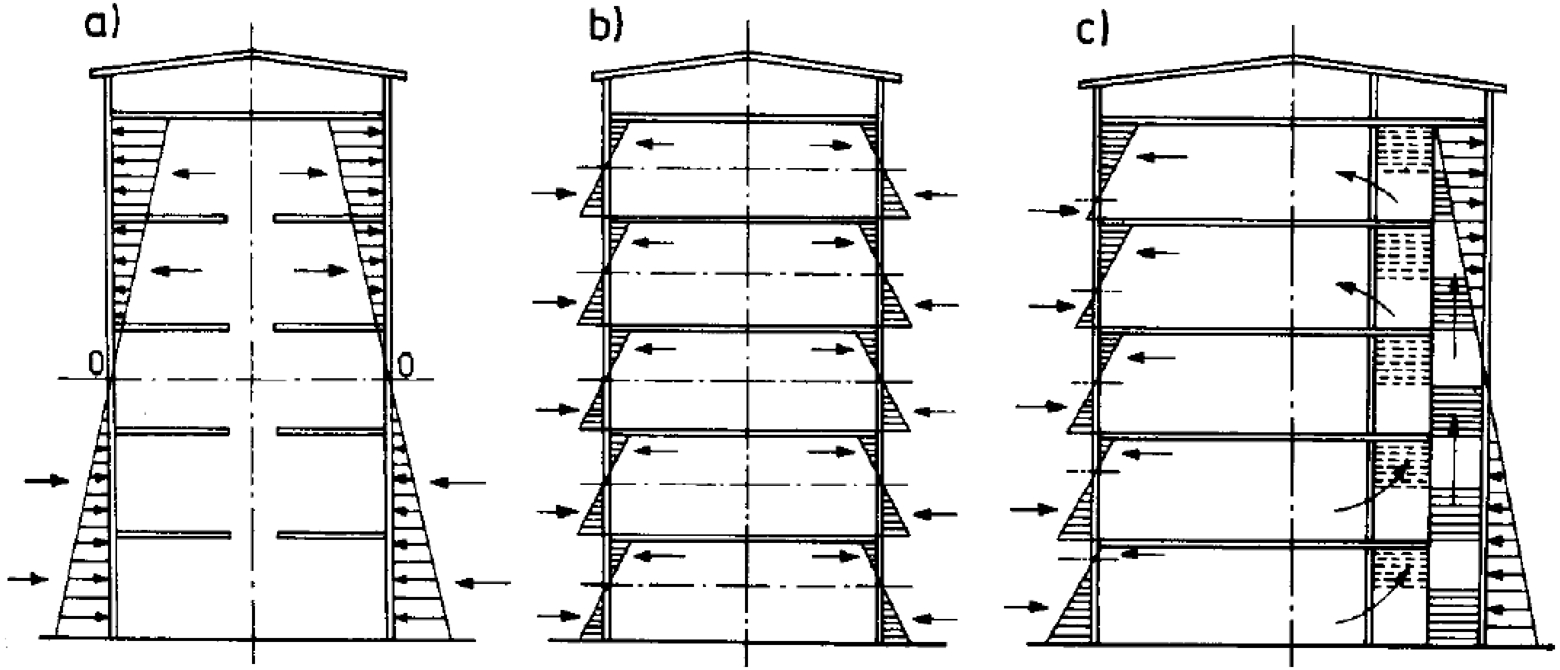
# Gravity effect

The placement of neutral pressure plane as a function of the opening areas:

$$\frac{z_1}{z_2} = \left(\frac{A_2}{A_1}\right)^2 \cdot \frac{\rho_z}{\rho_w}$$



# Gravity effect




a) the free flow between floors
b) air tight ceilings
c) some leakages

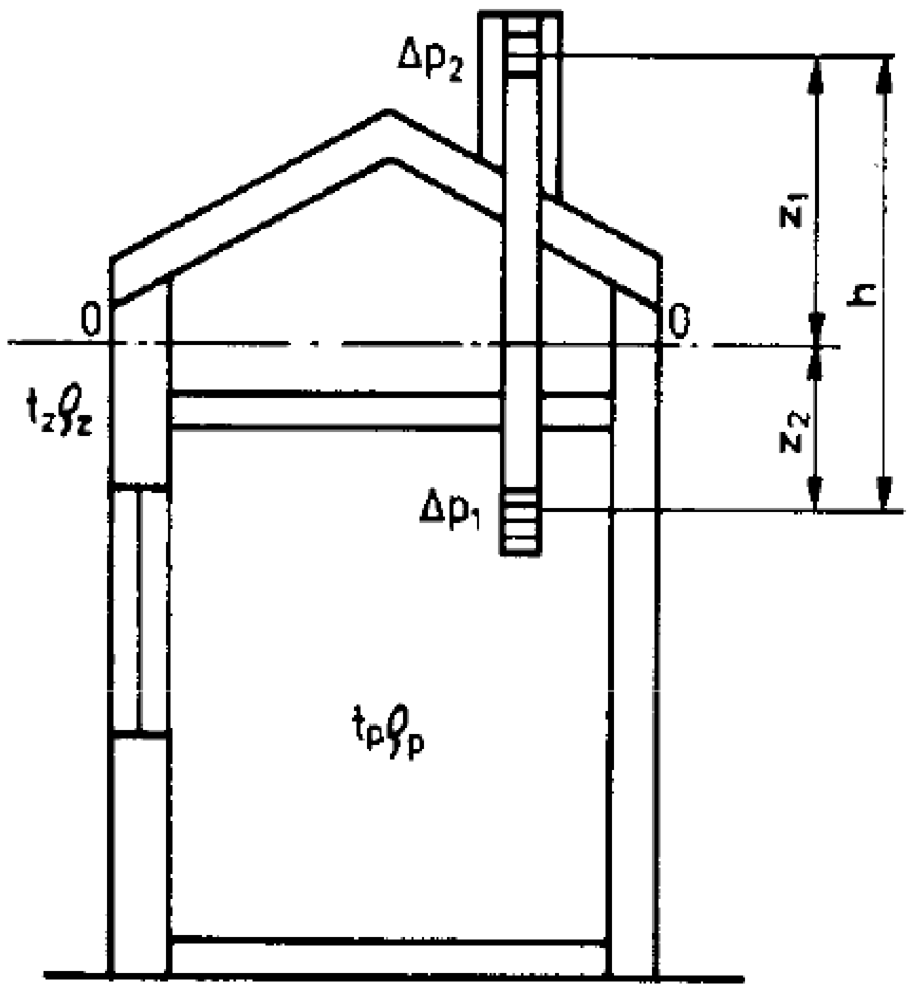
# Gravity effect

The calculations aim to balance the available pressure:

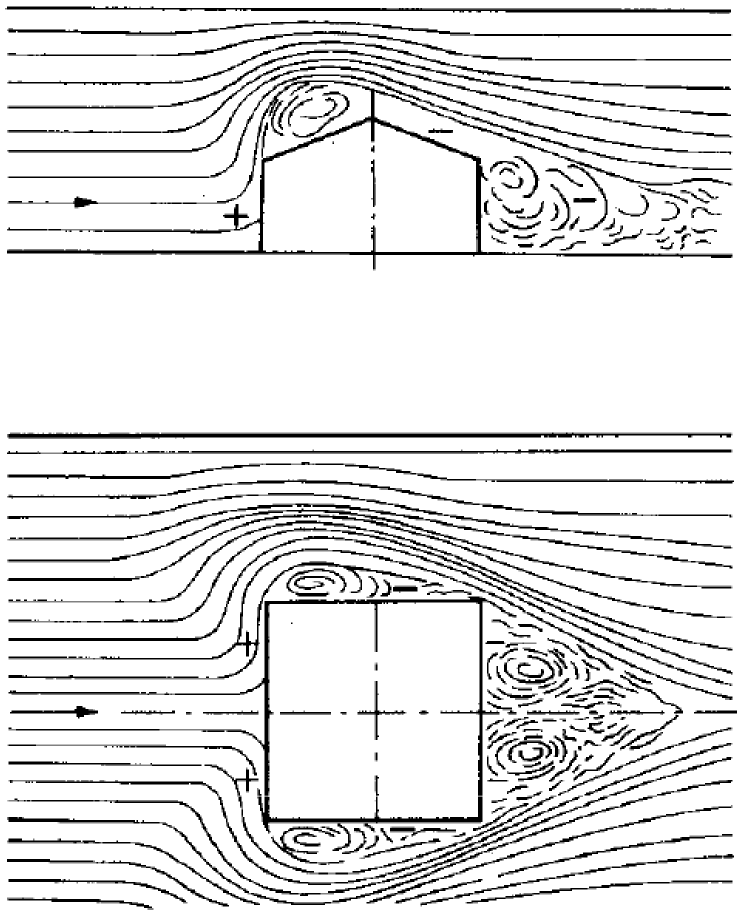
$$\Delta p_g = h \cdot g \cdot (\rho_z - \rho_w)$$

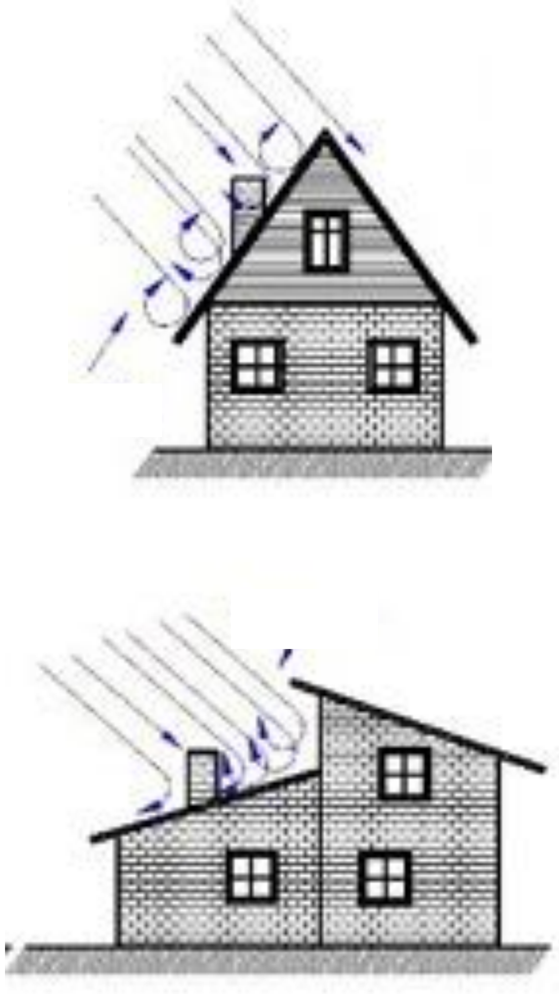
With the flow pressure drop:

$$\Delta p_g = \left( R_l \cdot h + \sum \xi \cdot \frac{\rho \cdot w_p^2}{2} \right)$$

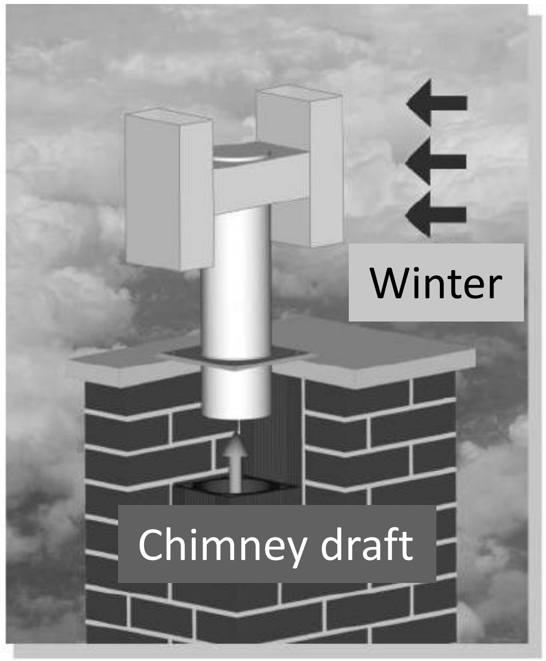


# Wind effect



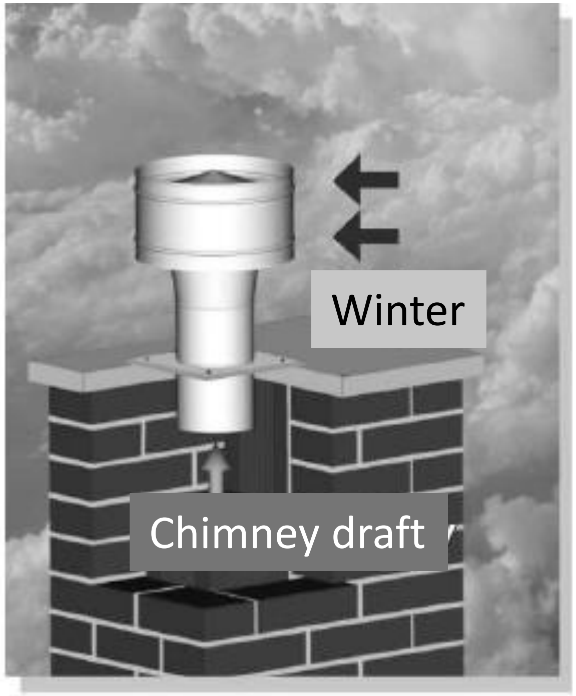


# Support of natural ventilation



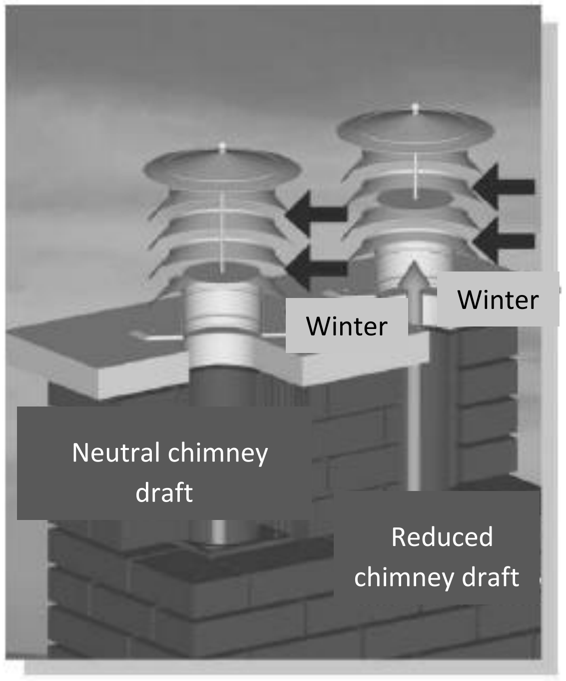

Device using kinetic energy of wind to increase the natural draft
Max. working temp. 180°C
Reducing negative effect of turbulences and strong wind

# Support of natural ventilation



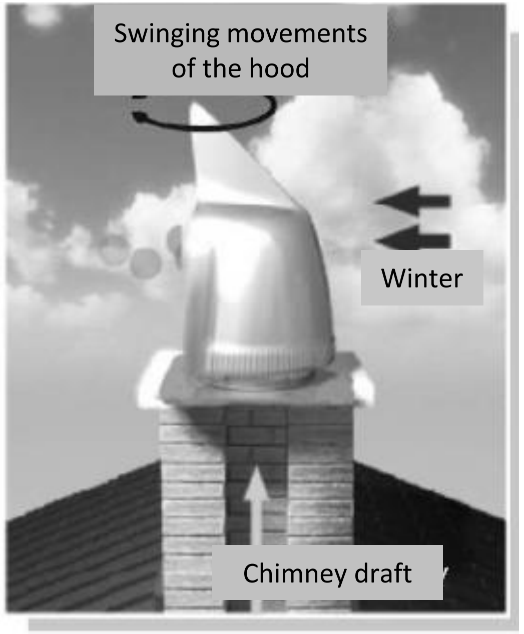

Cylindrical device using kinetic energy of wind to increase the natural draft
Max. working temp. 180°C
Reduces negative effect of turbulences and strong wind

# Support of natural ventilation



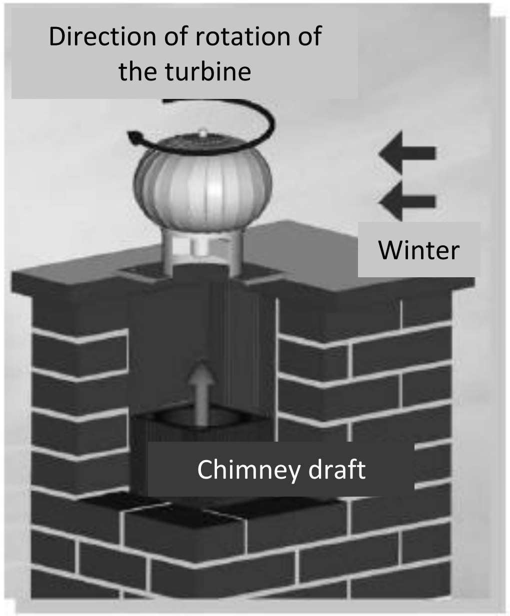

Ring-type device using kinetic energy of wind to increase the natural draft
Max. working temp. 400°C
Draft can be regulated

# Support of natural ventilation



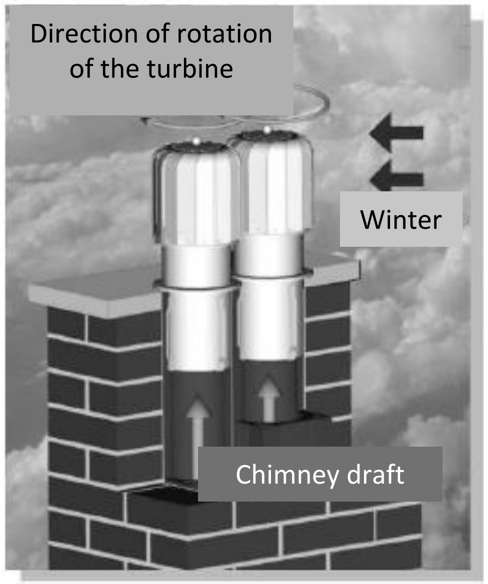

Self-adjusting device ROTOVENT uses the dynamic energy of wind to increase the natural draft by applying the vacuum effect
Max. working temp. 500°C (150°C)
For exhaust fumes and natural ventilation

# Support of natural ventilation



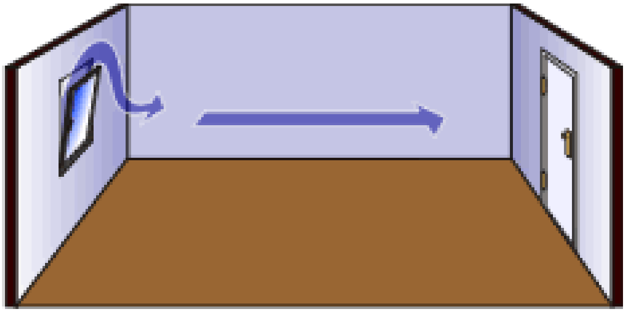

Rotating device TURBOVENT uses the dynamic energy of wind to increase the natural draft regardless of wind direction
Max. working temp. 150°C
For exhaust fumes and natural ventilation

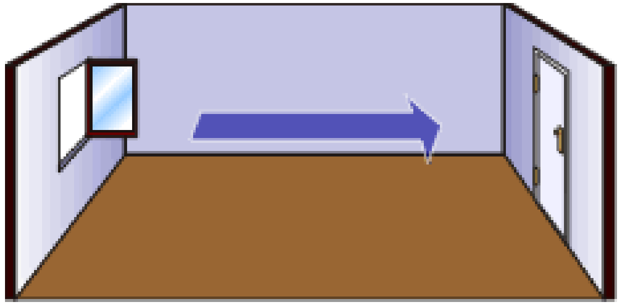
# Support of natural ventilation



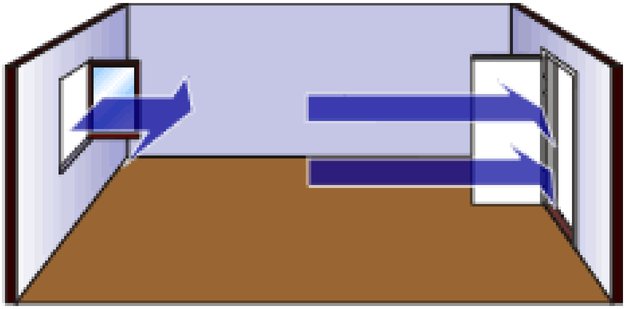

Rotating device TURBOVENT uses the dynamic energy of wind to increase the natural draft regardless of wind direction
Max. working temp. 150°C
For exhaust fumes and natural ventilation

# Natural ventilation by opening windows





"Stroke" ventilation



"Draft" ventilation

| State | Exchange rate [1/h] | Duration of one exchange [min] |
|---|---|---|
| Window and door shut | 0–0.5 | 120 |
| Slightly open window | 1.5–3 | 20–40 |
| Half-open window | 5–10 | 12–6 |
| Fully open window | 10–15 | 6–4 |
| Window and door open | to 40 | 1.5 |
| Slightly open top of window | 0.8–2 | 30–75 |
| Slightly open top of window with blinds | 0.5–1.3 | 45–120 |

# Part 2

# *Ventilation systems: hybrid, mechanical*

*Jarosław Müller*

# OUTLINE OF THIS PART:

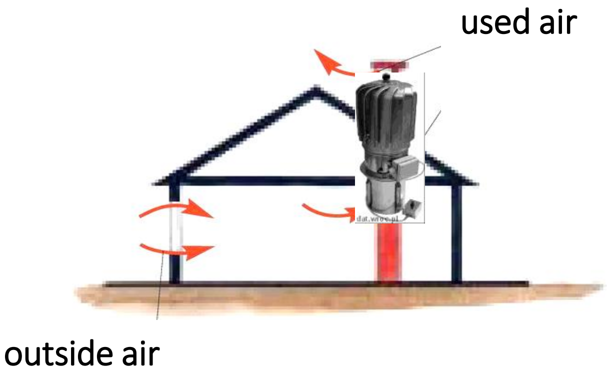
- Hybrid ventilation
- Mechanical ventilation
- Air ducts

# Hybrid ventilation

- Cap or hybrid ventilator
- Constant or alternate mechanical work
- Underpressure controlled
- Low energy demand

Caution!

- Air intake as in natural ventilation
- Only one room "served"!
- No wires allowed in shaft!




# Hybrid ventilation

## Turbowent tulipan hybrid

Regardless of wind direction, force and type, the cap rotates in the same direction creating the required underpressure. For the set rotation speed the cap is moved by the wind, if the wind is too strong, the motor reduces the rotation speed and for the lack of wind, the motor spins the cap.

Rotation control  170–430 [rpm]
Maximum air flow 230 [$m^3/h$]
Maximum temperature: 50 [°C]
Power demand 3–4 [W]


| Price netto/brutto |
| --- |
| 760.00/927.20 PLN |

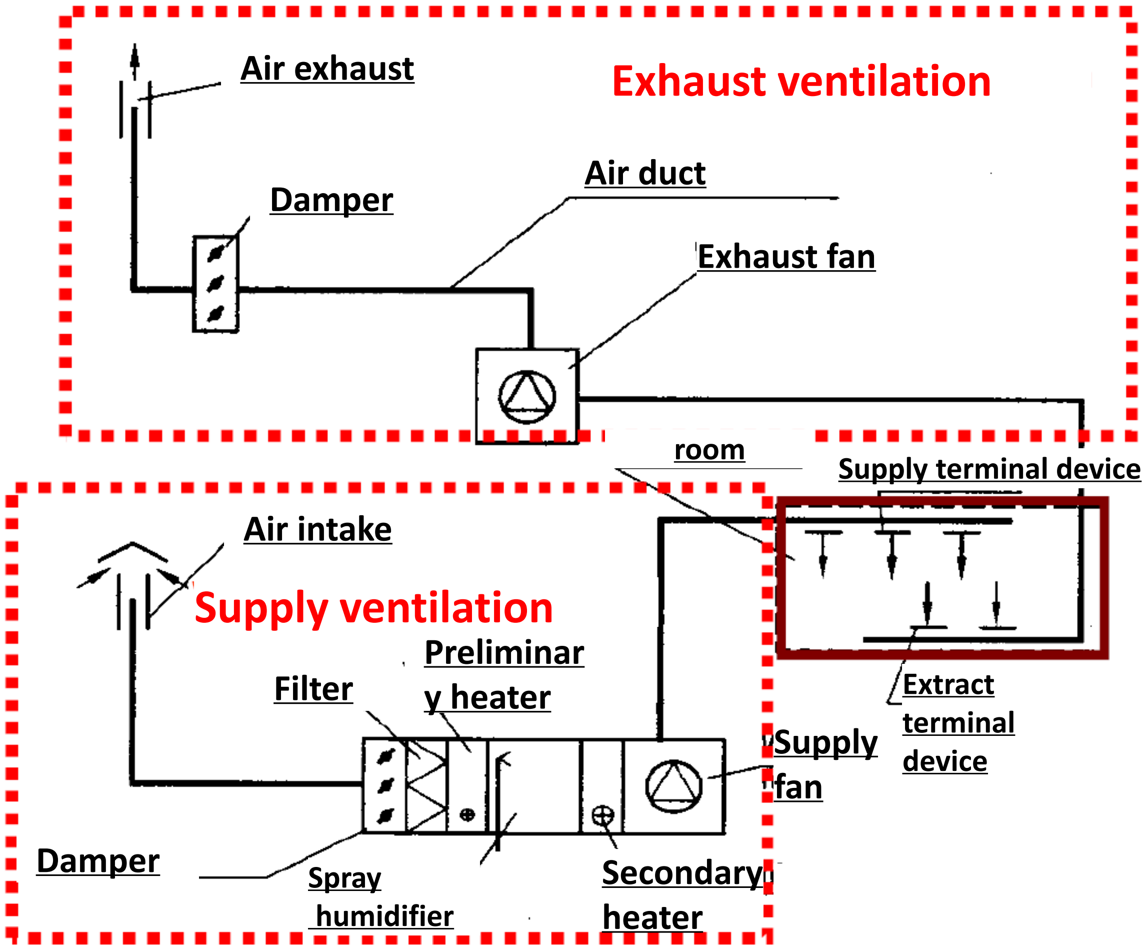
# Mechanical ventilation

- supply
- exhaust
- balanced
- quantitatively independent of external conditions
- enables air flow control
- enables air handling and heat recovery

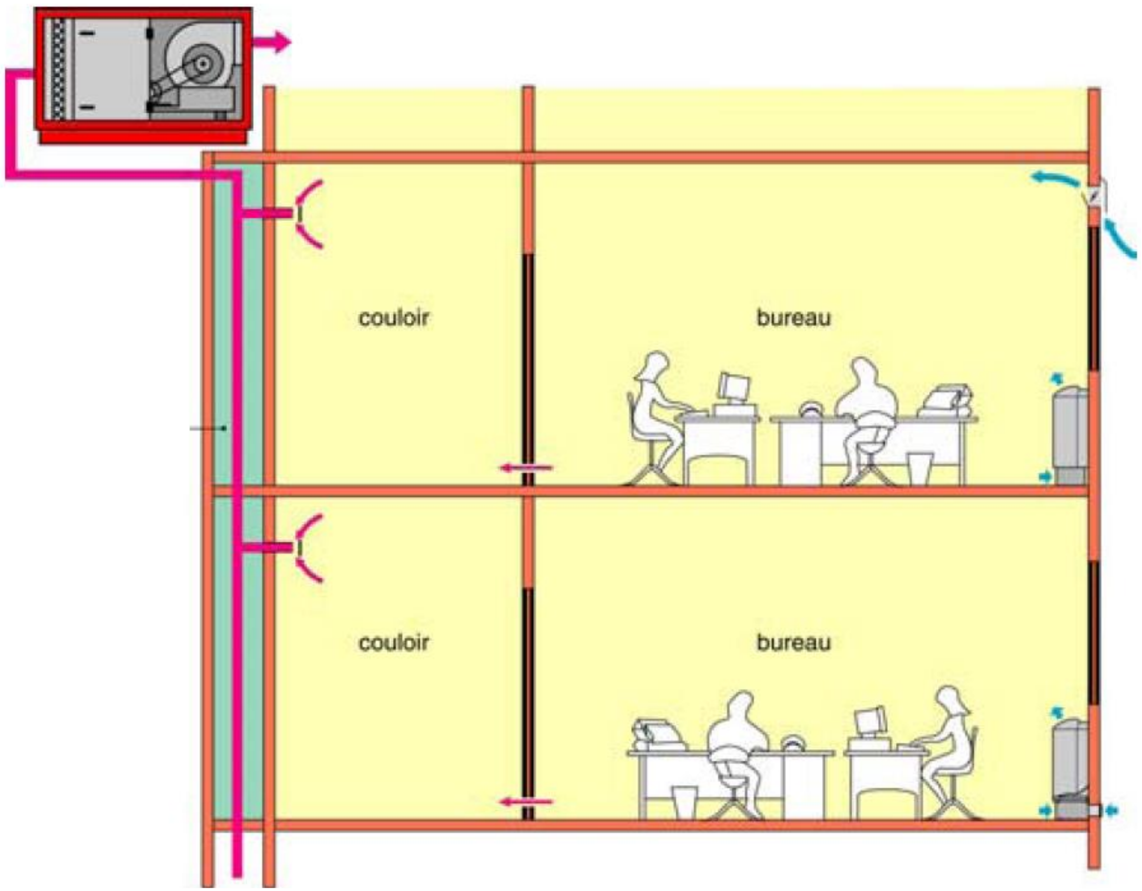
But:

- generates noise
- requires space for air handling unit (AHU)
- requires power supply

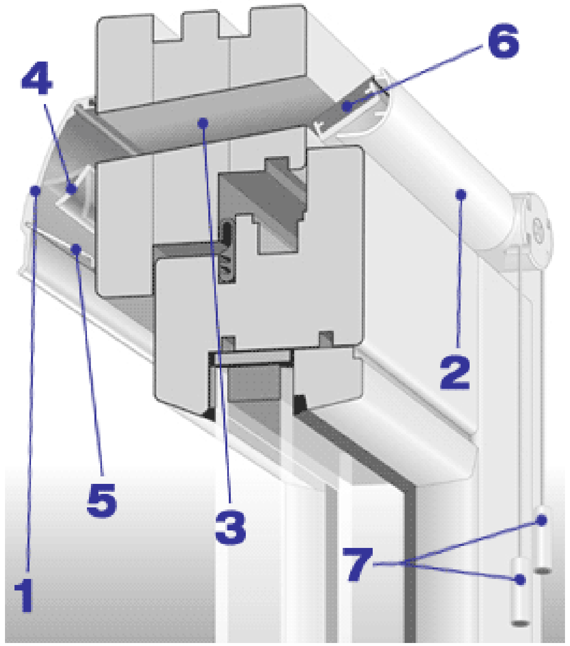
# Mechanical ventilation – system structure



# Mechanical ventilation: exhaust – only system



# Window diffuser




1 – intake

2 – controller

3 – slot

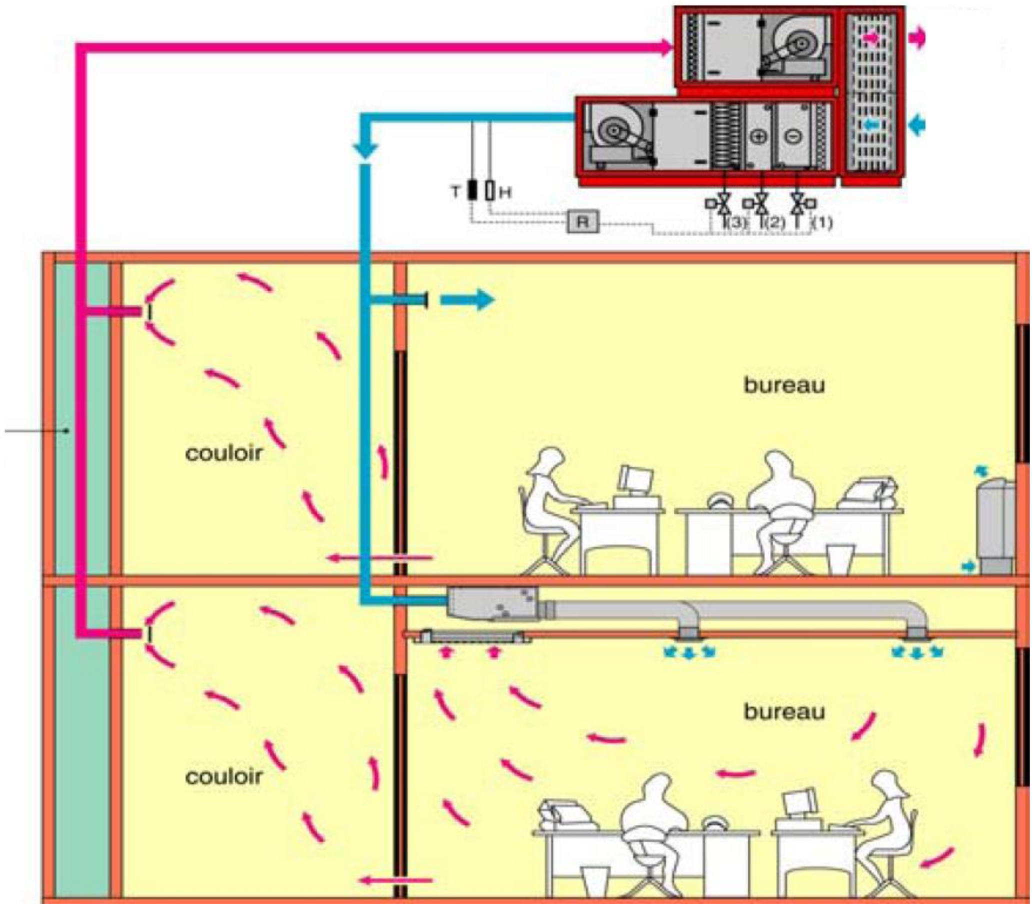
4 – aluminum plate

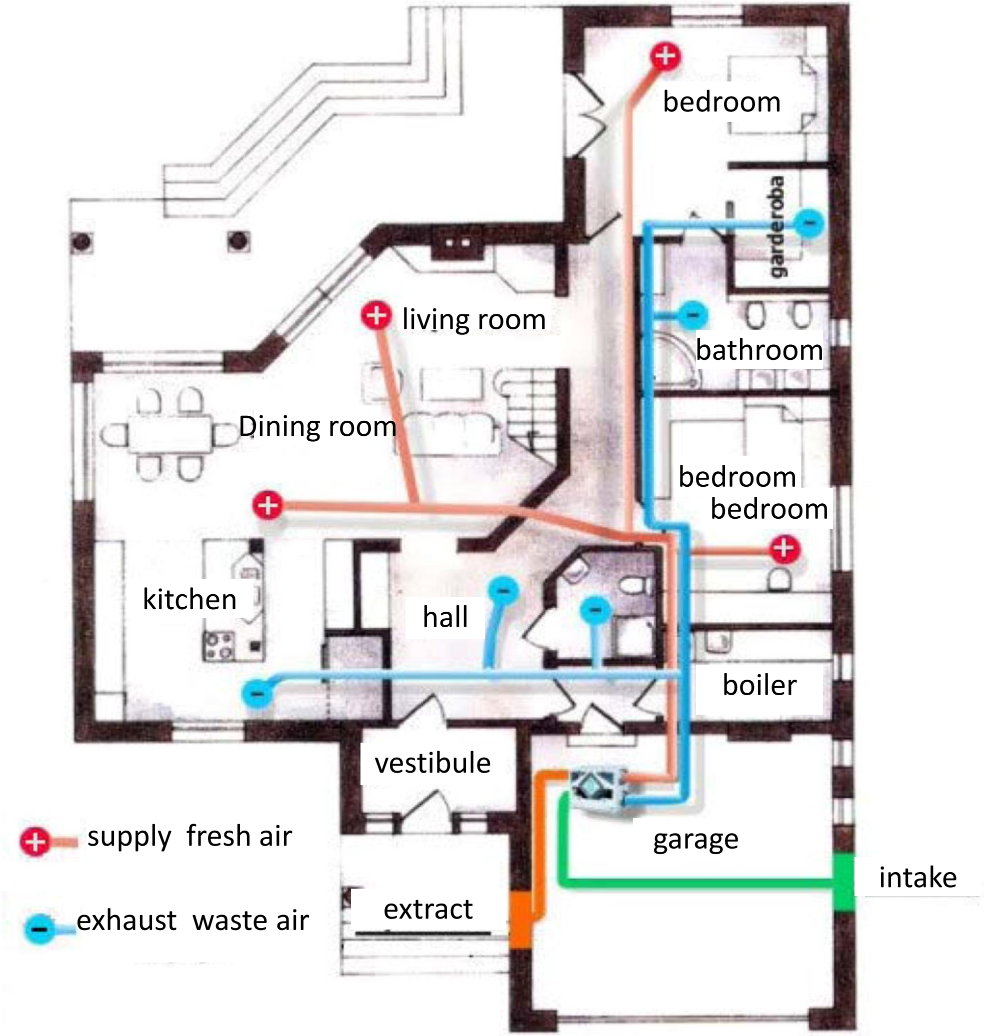
5 – mosquito net

6 – hinged flap

7 – strings with weights

# Balanced mechanical ventilation with heat recovery




bedroom
garderoba
living room
bathroom
Dining room
bedroom
bedroom
kitchen
hall
boiler
vestibule
supply fresh air
garage
intake
extract
exhaust waste air

# Local mechanical ventilation

- Kitchen hoods
- Displacement diffusers
- Bathroom exhaust fans?!

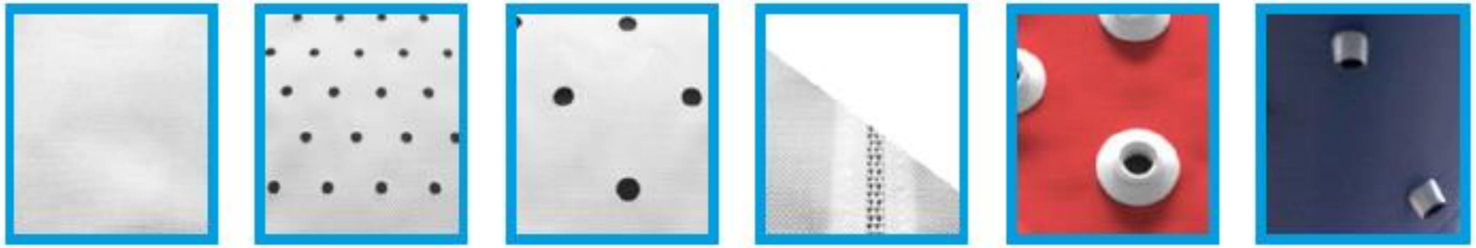
# Mechanical ventilation – components

- Fans
- Ductwork
- Terminal devices
- Accessories:
  - ✓ Filters
  - ✓ Dampers
  - ✓ heat exchangers
- Control devices

# Ductwork materials

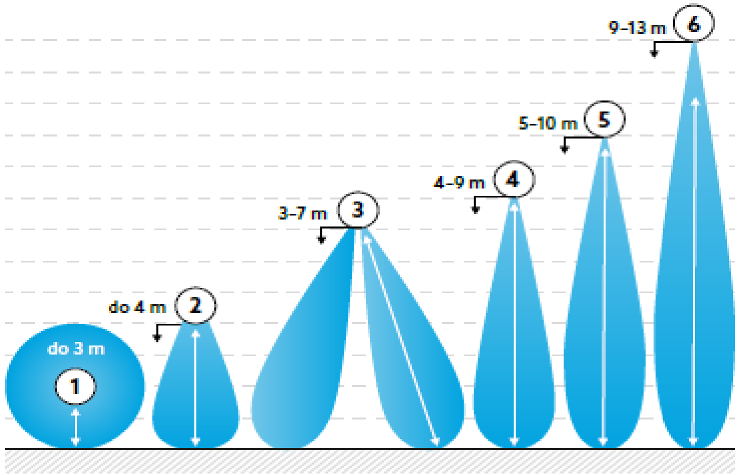
- Galvanized steel sheet,
- Aluminum plate,
- Stainless steel and acid resistant,
- Steel covered with lead,
- Plastics (PVC, PP, PU),
- Brick wall plastered on both sides,
- Monolithic concrete wall,
- Fabric,
- Stoneware,
- Fiberglass,
- Other materials approved by hygienic and fire certificates.

# Fabric ducts

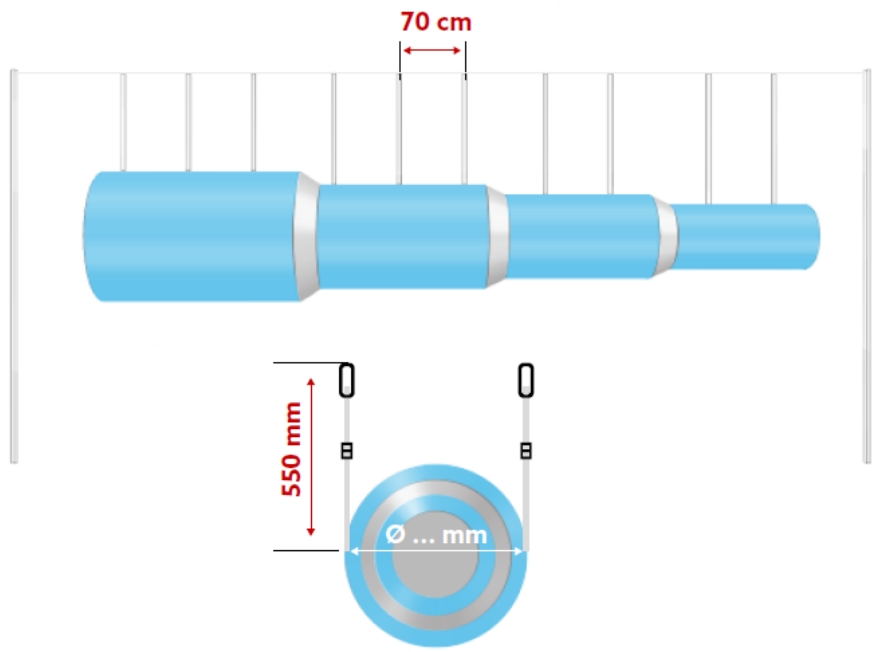


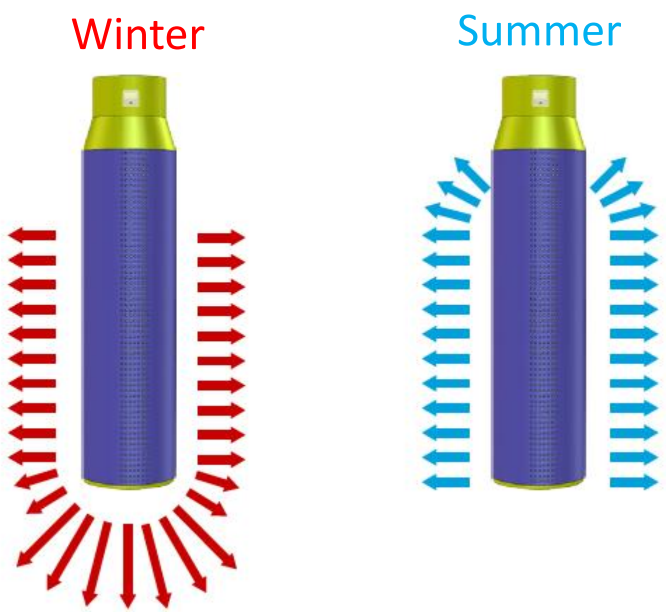
**Permeable material** | **Micro-perforation (openings diameter: 0.2-0.4 mm)** | **Perforation (openings diameter: 4-9 mm)** | **Slot** | **Nozzle** | **Long-range nozzle**

1. Permeable material
2. Microperforation
3. Slot
4. Perforation
5. Nozzles
6. Long range nozzles



# Fabric ducts



# Fabric ducts

# Recommendations for intake of fresh air (by: „Technical conditions…”, 152)

1. Air intakes for ventilating and air-conditioning should be protected from rain and the wind, and should be located in such a way that the air taken is the purest and, in summer, the coolest.
2. Air intakes placed on terrain level or on the wall of the two lowest floors should be located in a distance of 8 m from the streets and parking lots, waste disposals and other pollution sources. The distance of the bottom part of the intake from the ground: min 2 m.

# Recommendations for intake of fresh air (by: PN-EN 13779)

- > 8 m of horizontal distance from a garbage collection point, frequently used parking area, diveways, sewer vents, chimney heads
- No air intake should be positioned on a facade **exposed to a busy street**. (at least the opening should be positioned as high as possible)
- No air intake should be positioned just above the ground. At least 1.5 times the maximum expected thickness of snow
- Maximum air velocity in the opening: 2 m/s.
- Consideration should be given to the possibility for cleaning

# Recommendations for air exhaust (by: PN-EN 13779)

- Distance – at least 8 m from an adjacent building
- Distance in at least 2 m from an intake opening in the same wall (intake below discharge)
- Air velocity in the discharge opening is at least 5 m/s

# Specific fan power (by PN-EN 13779)

$$P_{SFP} = \frac{P}{q_v} = \frac{\Delta p}{\eta_{tot}}$$

where:

$P$ – input power of the motor for the fan [W]

$q_v$ – nominal airflow through the fan [$m^3/h$]

$\Delta p$ – total pressure difference across the fan

$\eta_{tot}$ – total efficiency of fan, motor and drive

# Specific fan power (by PN-EN 13779)

Examples for efficiency for specific components in central air system

| Component | Efficiency in % | | |
|---|---|---|---|
| | Low | Normal | High |
| Fan based on total pressure | 65 | 75 | 80 |
| Fan based on static pressure | 55 | 65 | 70 |
| Motor < 1.1 kW | 70 | 77 | 80 |
| Motor < 3.0 kW | 75 | 82 | 85 |
| Motor < 7.5 kW | 80 | 87 | 90 |
| Motor < 7.5 kW | 82 | 89 | 92 |
| Belt drive < 1.1 kW | 70 | 75 | 80 |
| Belt drive < 3.0 kW | 75 | 80 | 85 |
| Belt drive < 7.5 kW | 80 | 85 | 90 |
| Belt drive > 1.1 kW | 85 | 90 | 95 |
| Flat belt | 90 | 93 | 97 |
| Frequency inverter | 88 | 92 | 97 |
| | | | |
| Total fan unit | 50 | 55 | 60 |

# Specific fan power (by PN-EN 13779)

Examples for pressure drops for specific components in air handling systems

| Component | Pressure losses in Pa | | |
|---|---|---|---|
| | Low | Normal | High |
| Ductwork supply | 200 | 300 | 600 |
| Ductwork exhaust | 100 | 200 | 300 |
| Heating coil | 40 | 80 | 100 |
| Cooling coil | 100 | 140 | 200 |
| Heat recovery unit H3[a] | 100 | 150 | 250 |
| Heat recovery unit H2–H1[a] | 200 | 300 | 400 |
| Humudifier | 50 | 100 | 150 |
| Air washer | 100 | 200 | 300 |
| Air filter F5–F7 per section[b] | 100 | 150 | 250 |
| Air filter F8–F9 per section[b] | 150 | 250 | 400 |
| HEPA Filter | 400 | 500 | 700 |
| Gas Filter | 100 | 150 | 250 |
| Silencer | 30 | 50 | 80 |
| Terminal device | 30 | 50 | 100 |
| Air inlet and outlet | 20 | 50 | 70 |

[a] Class H1–H3 according to EN 13053.
[b] Final pressure drop before replacement.

# Specific fan power (by PN-EN 13779)

$$SFP = \frac{P_{sf} + P_{ef}}{q_{\max}}$$

where:
$P_{sf}$ – total power input for supply fans
$P_{ef}$ – total power input for exhaust fans
$q_{max}$ – total airflow in the building (exhaust)

# Classification of installation

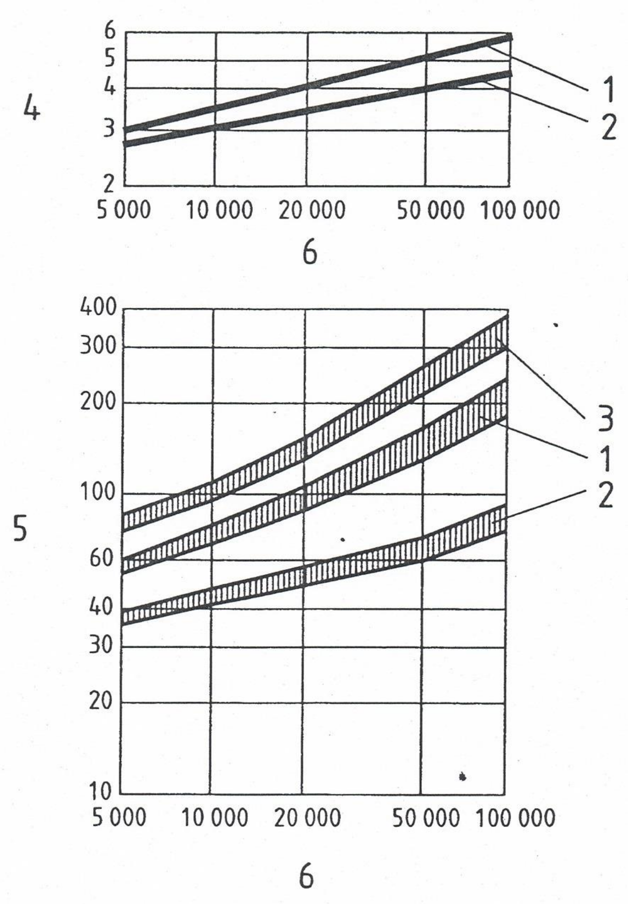
| Installation category | $P_{SFP}$ [W/m³/s)] |
|---|---|
| SFP 1 | < 500 |
| SFP 2 | 500–750 |
| SFP 3 | 750–1250 |
| SFP 4 | 1250–2000 |
| SFP 5 | 2000–3000 |
| SFP 6 | 3000–4500 |
| SFP 7 | > 4500 |

# Examples (by PN-EN 13779)

Examples for the category of *SFP*

| Application | Category of *SFP* for each fan | |
|---|---|---|
| | Typical range | Default value |
| Supply air fan<br>• air-conditioning system<br>• ventilation system without heat recovery | *SFP* 1 to *SFP* 5<br>*SFP* 1 to *SFP* 4 | *SFP* 4<br>*SFP* 3 |
| Extract air fan<br>• air-conditioning system, or ventilation system with heat recovery<br>• ventilation system without heat recovery | *SFP* 1 to *SFP* 5<br>*SFP* 1 to *SFP* 4 | *SFP* 3<br>*SFP* 2 |

# Space requirements for plant-rooms




**Key**

| | | | |
|---|---|---|---|
| 1 | Supply air system (top graph)<br>Supply air system only (bottom graph) | 4 | Room height in m |
| 2 | Extract air system (top graph)<br>Extract air system only (bottom graph) | 5 | Floor area in $m^2$ |
| 3 | Supply and extract air system (top graph) | 6 | Supply or extract airflow rate in $m^3.h^{-1}$ |

# Part 3

# *Air – conditioning systems*

*Jarosław Müller*

# OUTLINE OF THIS PART:

- Definition
- CAV system
- VAV system
- Air-water systems
- Direct evaporating systems

# Definition of an air conditioning system

Air conditioning is a **ventilation** providing certain parameters (air quality, temperature, relative humidity) by air handling and distribution according to the room purpose in **any** outside and inside conditions.
Air conditioning takes into consideration human comfort or technological requirements.

# A difference between ventilation and air-conditioning

**Ventilation**

- responsible for air flow
- no recirculation
- setpoint: supply air parameter

**Air-conditioning**

- ventilates
- responsible for indoor air parameter(s)
- supplied air flow is the sum of fresh and recirculating air

# Air conditioning systems

Air systems ("full" air conditioning)

- System CAV (Constant Air Volume)
- System VAV (Variable Air Volume)

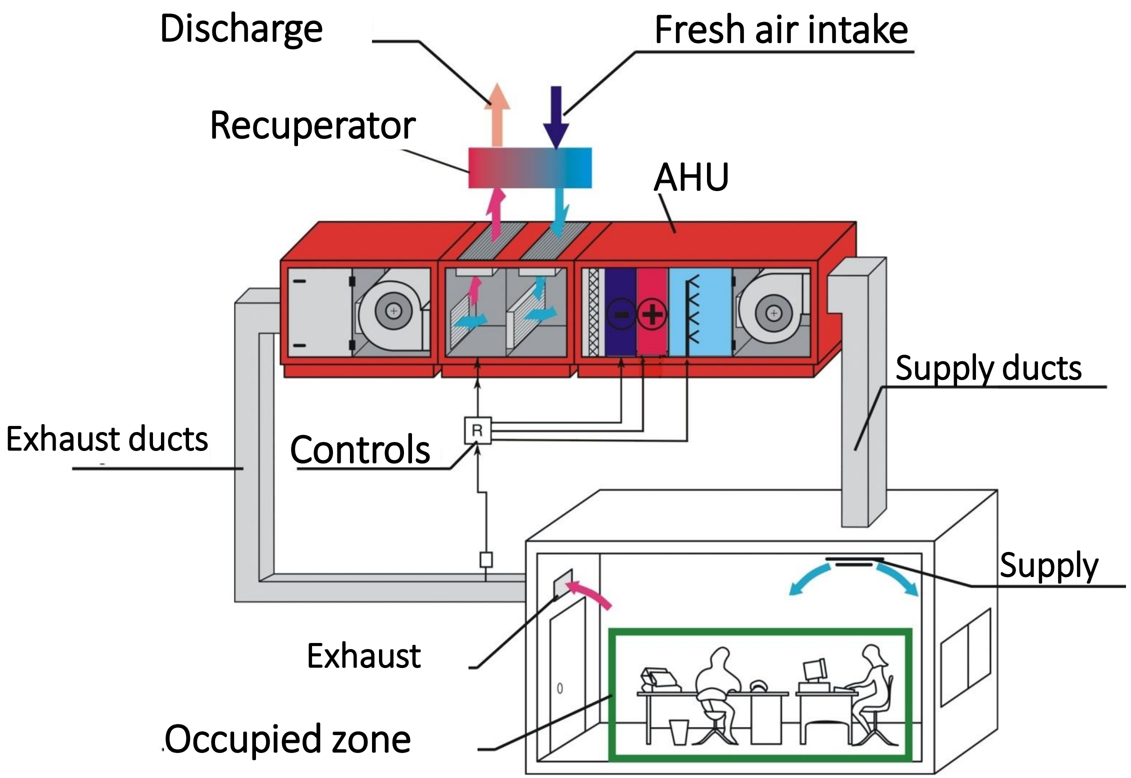
Air – water systems(with secondary air handling)

- fan-coils "wet"
- fan-coils "dry" (chilled beams, cool ceilings)

Direct evaporation systems

- multi split (+VRF)
- room air conditioners

# System CAV (Constant Air Volume)

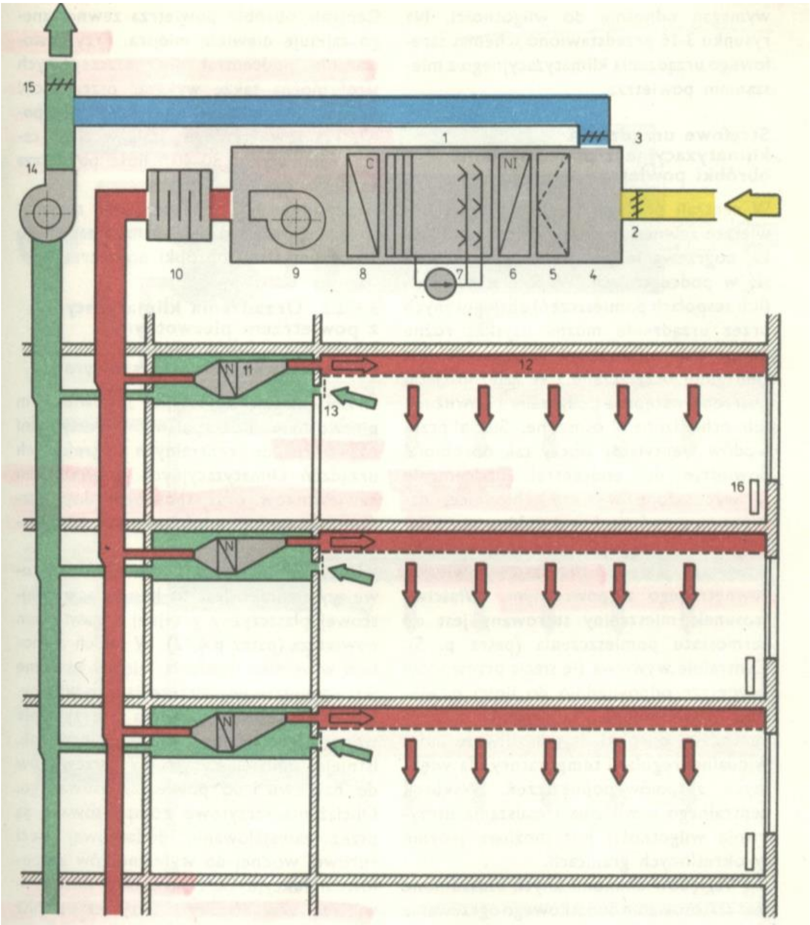


# System CAV (Constant Air Volume)

ADVANTAGES
- suitable for single room
- temperature, relative humidity, air quality control

DISADVANTAGES
- large ducts
- space required for AHU
- zone devices

# System CAV Zones



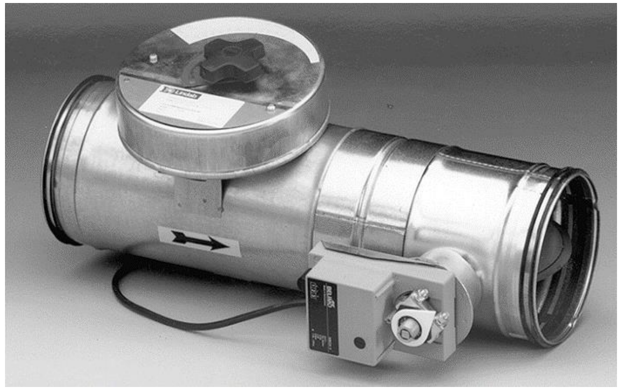
# SYSTEM VAV (Variable Air Volume)

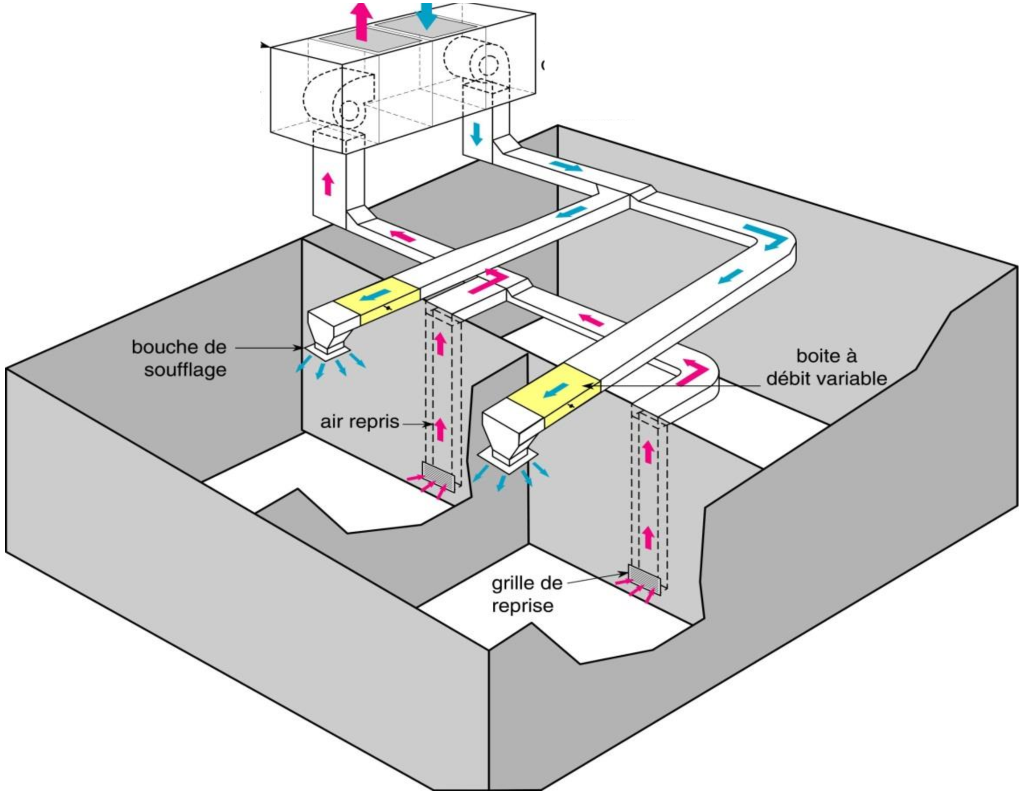
PRO:

- temperature and airflow controlled independently in several rooms
- quick response
- partly reduced size of air ducts
- partly reduced plant-room size
- fan power savings

CONTRA:

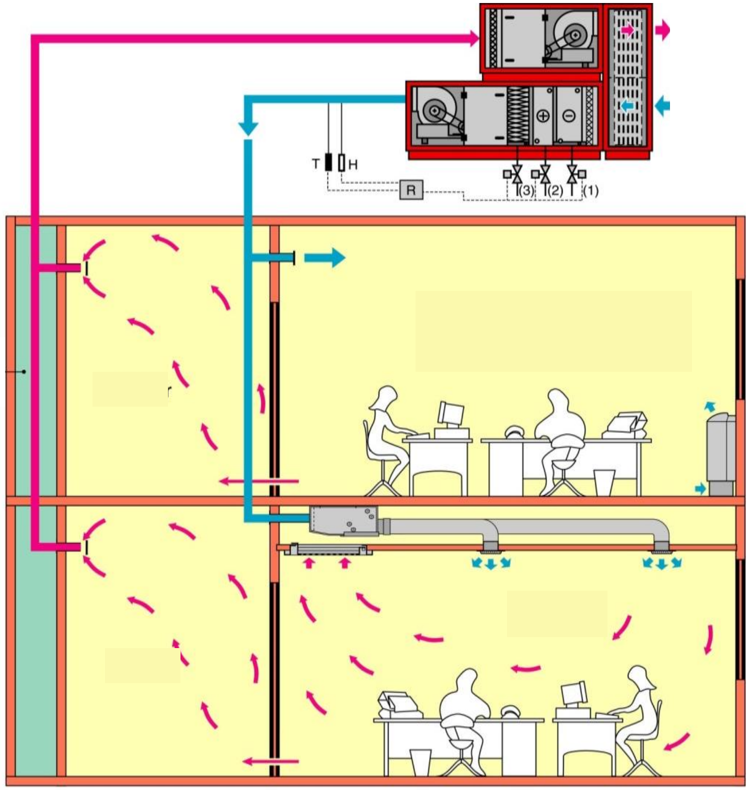
- cost (controls)
- noise





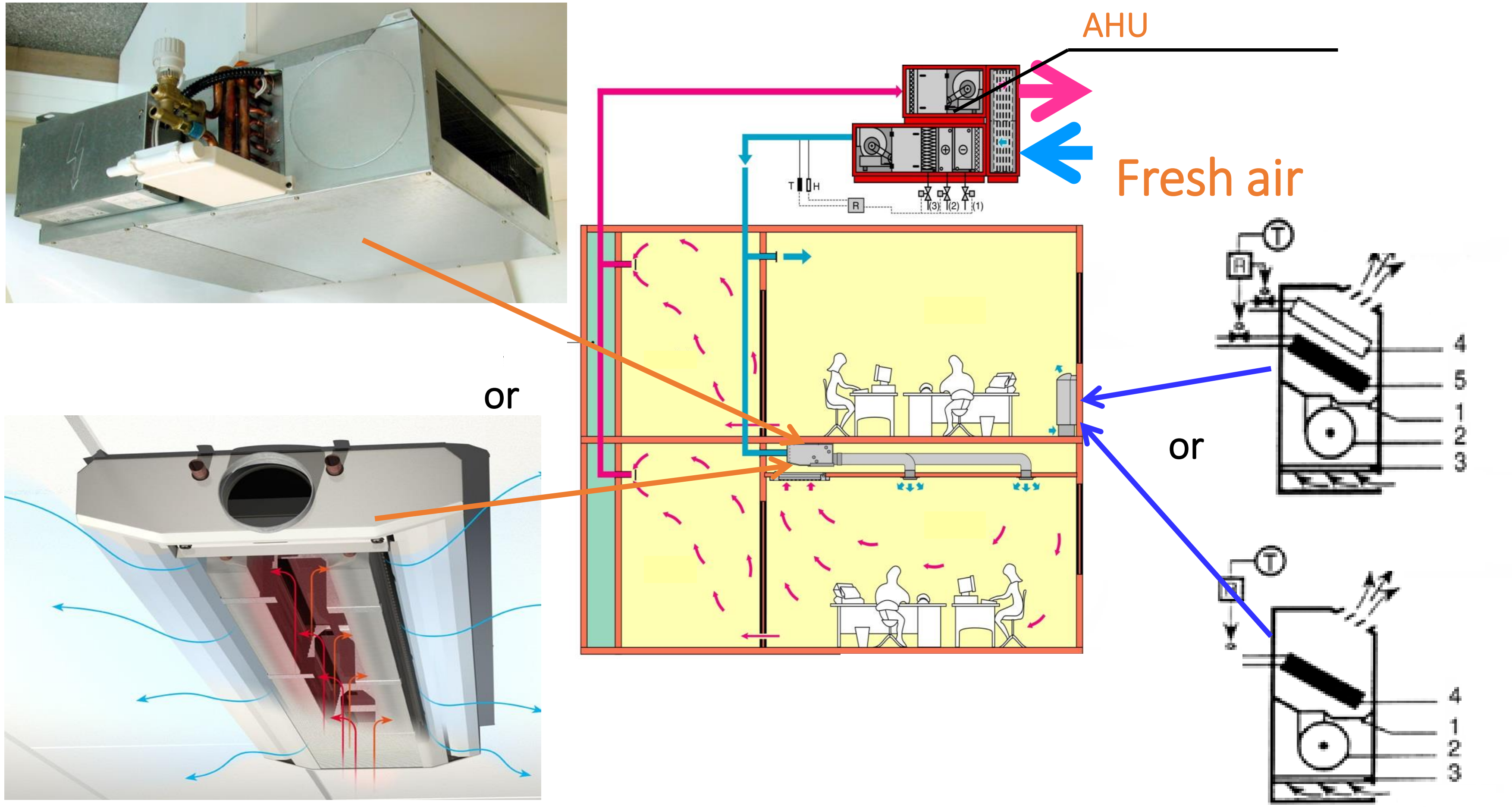

*Source: SMAY*

# Air – water systems
## Fan-coils (dehumidifying)




*Source: CIAT*

# Air – water systems




*Source: CIAT*

# Air – water systems

## Fan-coils (dehumidifying)

PRO:

- individually controlled airflow, temperature, air quality (limited)
- small size of air ducts (minimum of fresh air)
- uncontrolled dehumidification

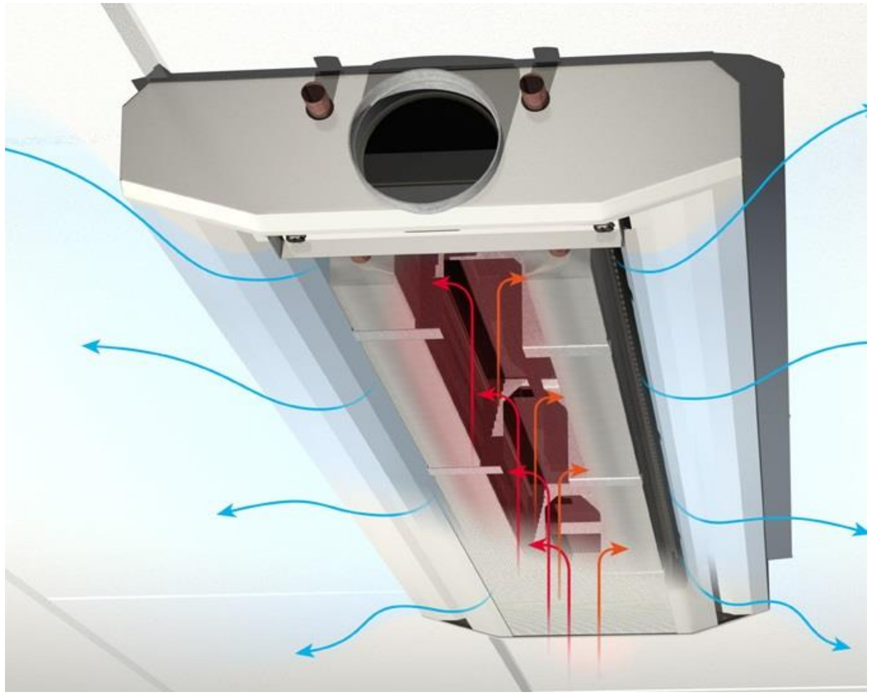
CONTRA:

- extra piping, drain piping

# Air – water systems

**Dry fan-coils**

**Chilled beams – no water condensation**



# Cool ceilings – no water condensation

Capilary matts

Units

*Source: hennlich.pl*

# Air – water systems – dry

## Fan-coils (chilled beams, cool ceilings) – no water condensation

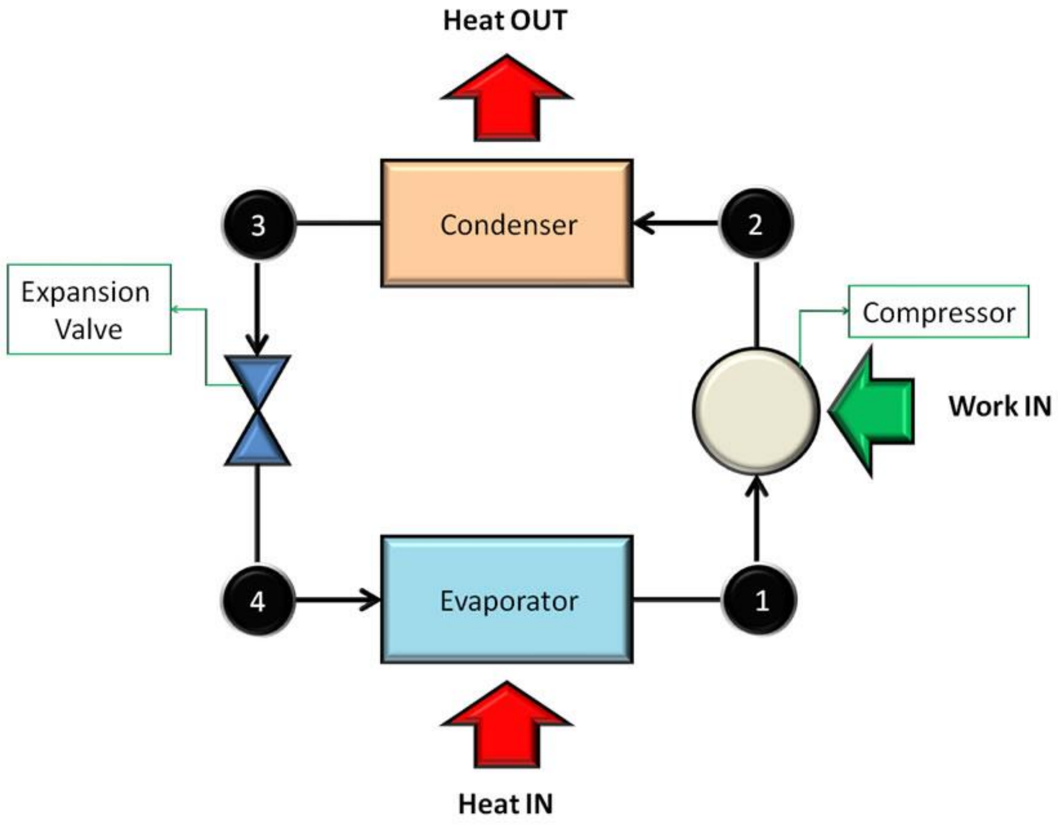
Pro:

- individually controlled airflow, temperature, air quality (limited – only in fan – coils)
- small size of air ducts (minimum of fresh air)
- beams and ceilings – very quiet
- radiation

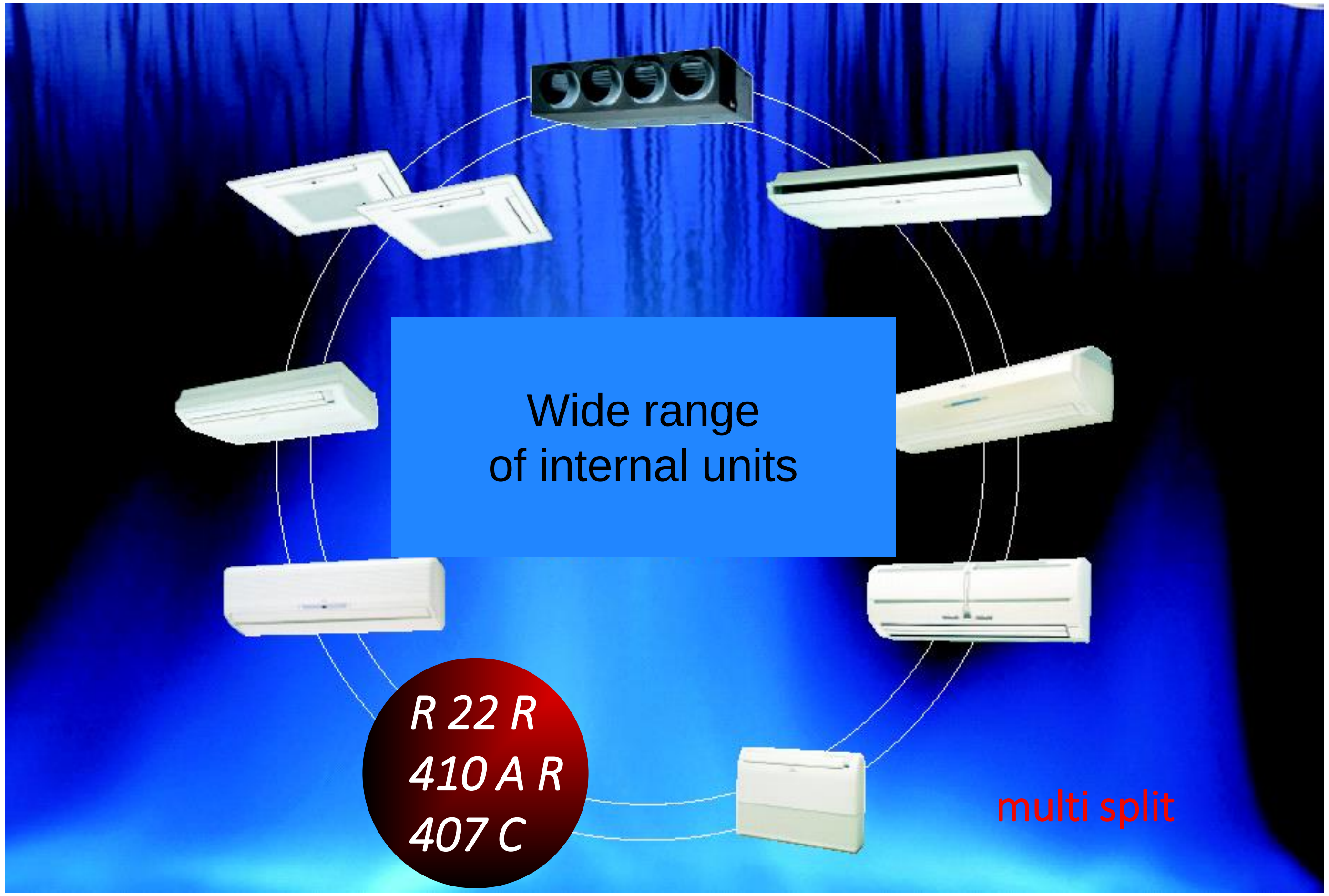
Contra:

- extra piping
- very precisely controlled wet bulb temperature required
- low cooling capacity (large sizes)

# Direct evaporating systems



# Direct evaporating systems




*Source: fujitsu.pl*

# Direct evaporating systems

Pro:

- individually controlled airflow, temperature, air quality (limited)
- intensive dehumidification

Contra:

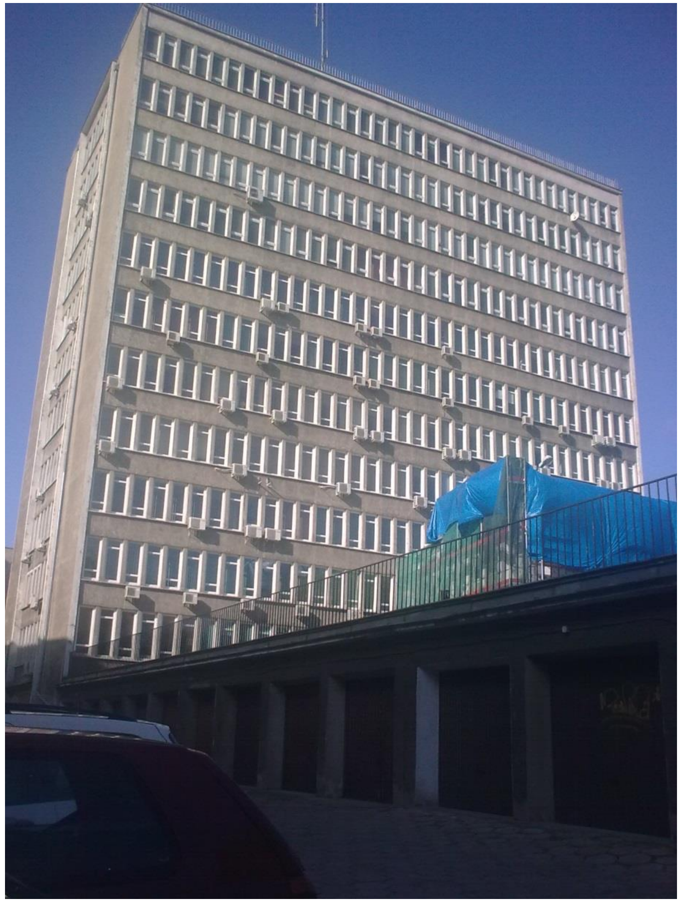
- extra refrigeration piping
- restrictions according to PN-EN 378

# Direct evaporating systems
## Room air-conditioners

**Pro:**
- individually controlled airflow, temperature, air quality (limited)
- intensive dehumidification
- simple installation

**Contra:**
- window or outside wall
- "one point" supply

# Split system



# The choice

- The vast range of available systems gives the oportunity to adjust the designed system to individual requirements and expectations of the investor/user.
- An engineer is supposed to present every solution with its advantages and disadvantages.
- There are no "standard solutions" – but sometimes we find "a commonly used" system that does not have to be the optimal nor the best.

# Part 4

## *Systems for single-family houses*

*Jarosław Müller*

# OUTLINE OF THIS PART:

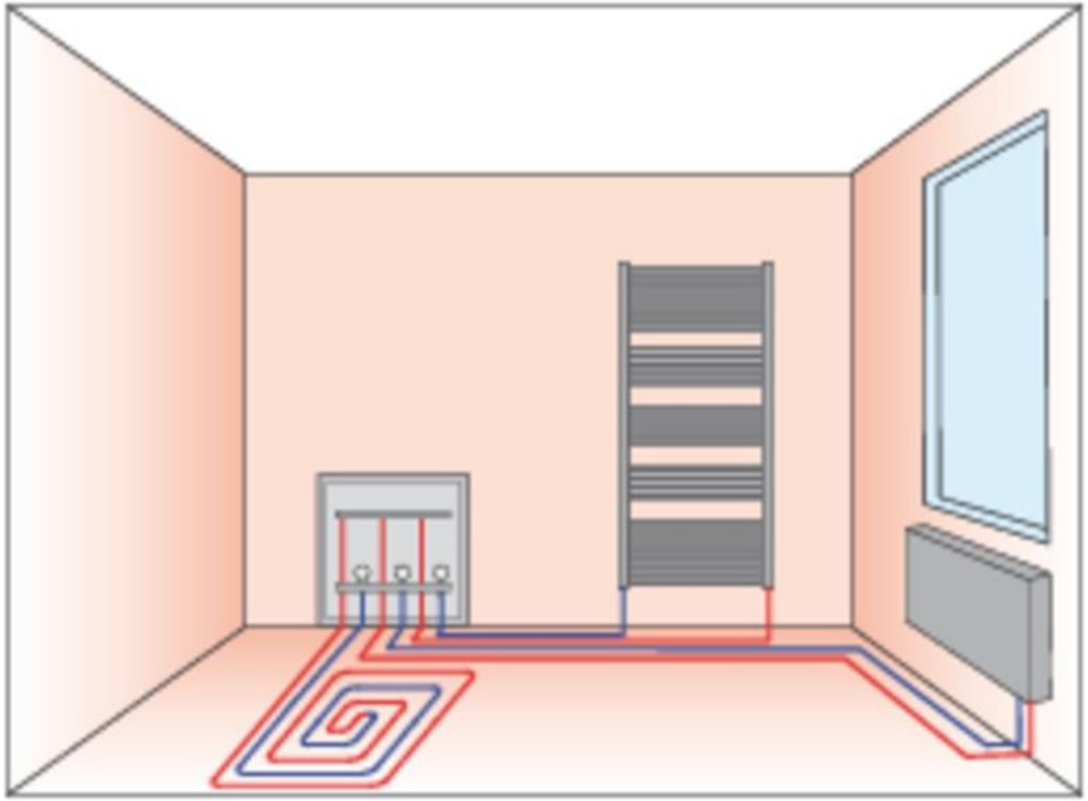
- Surface heating systems
- Air heating systems
- Air distribution
- Ground – source heat exchanger

# Main topics for heating systems

- Operation time, stop time
- Heating on duty
- Control
- Cooperation with ventilation
- Adaptation to requirements
- Source of heat

# Surface heating

# Surface heating



*Source: archipelag.pl*

The distributor system does not exclude cooperation of different types of heaters

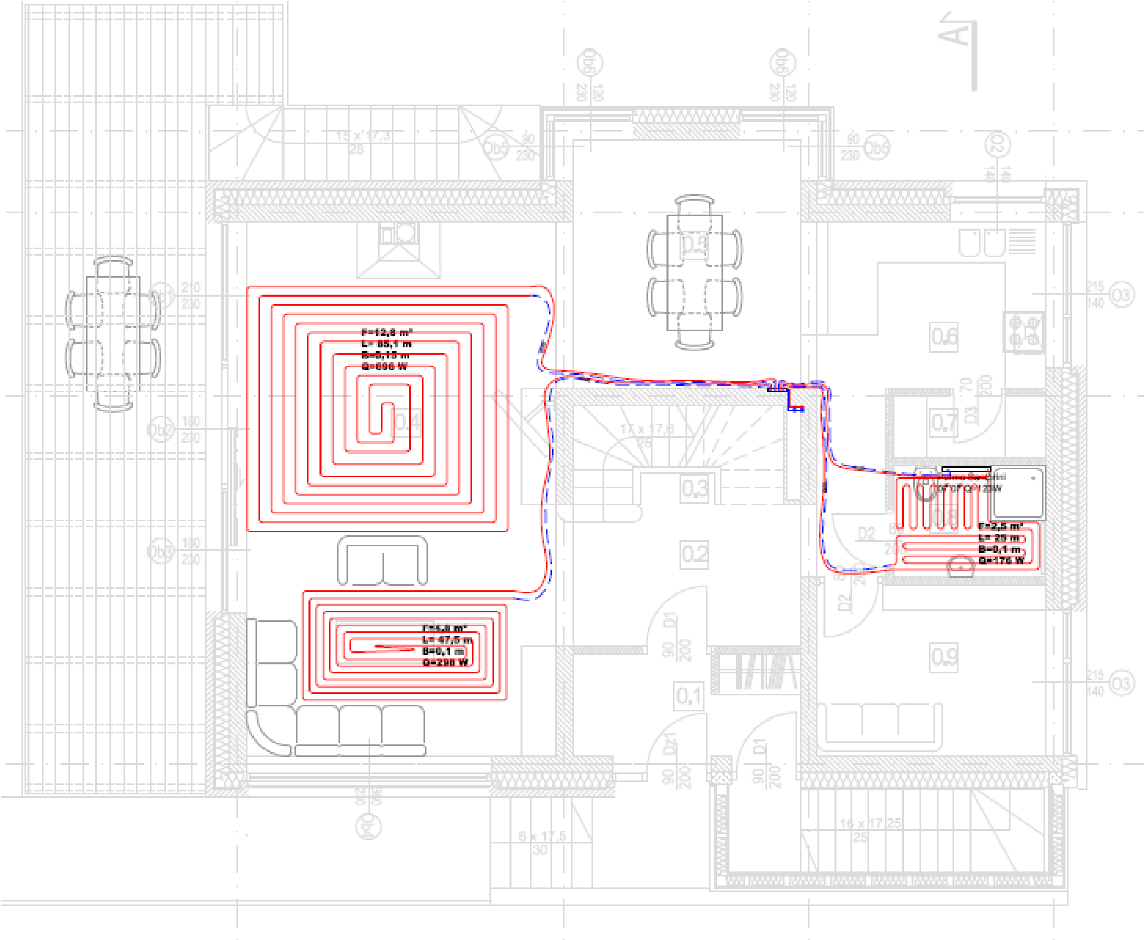
Supply temperature = $T_{max}$

# Surface heating-floor

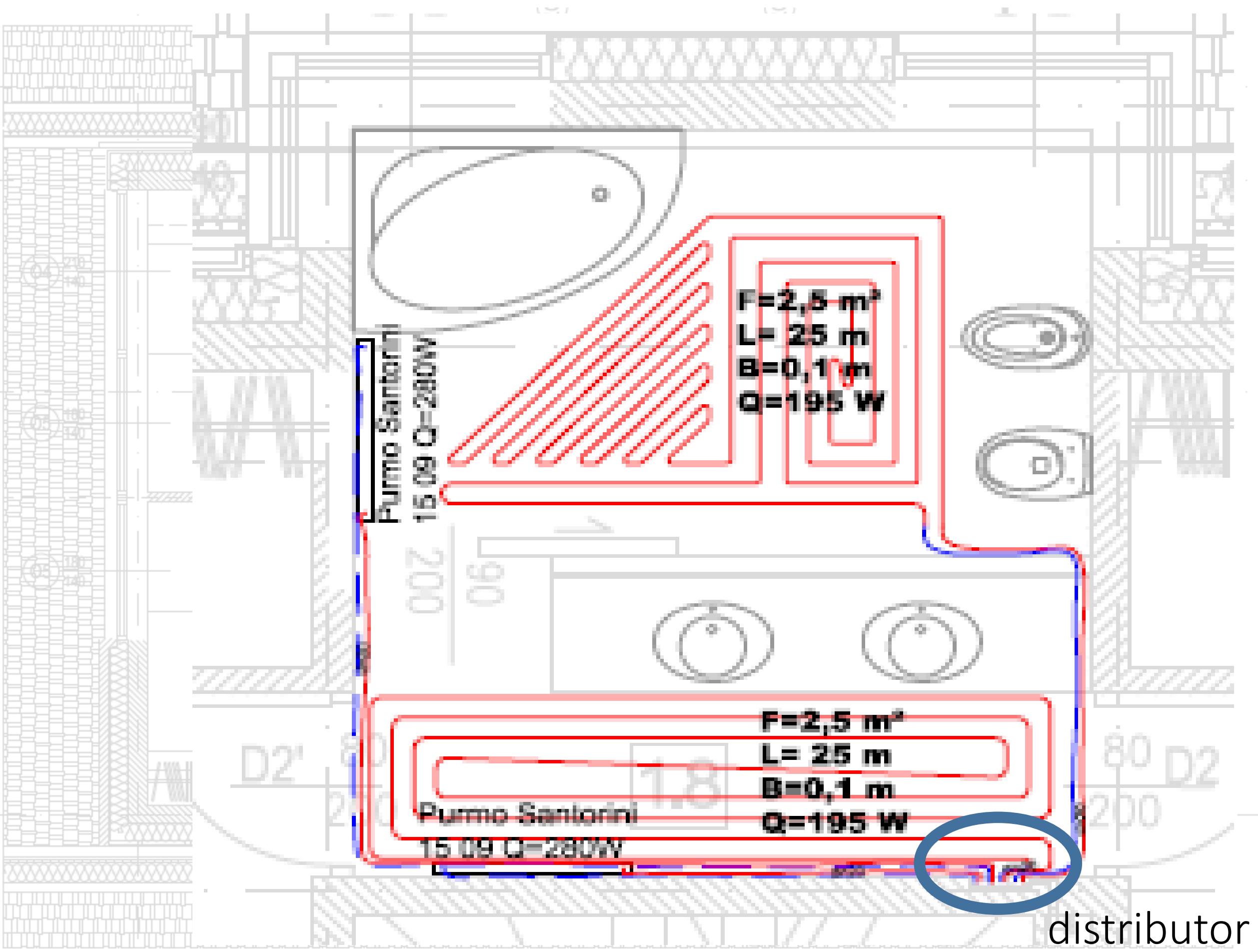
- inert
- self-regulating
- drying of dust

*Photo by B. Maludziński*

# Surface heating-floor

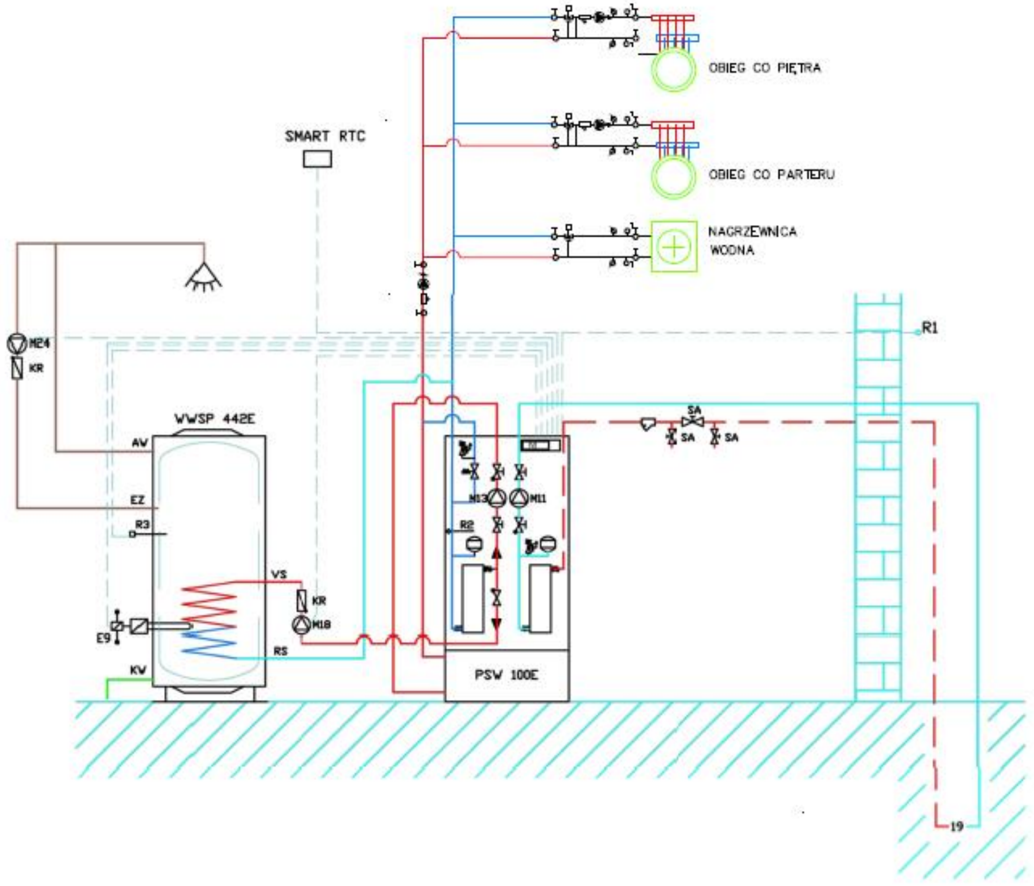


# Surface heating-floor



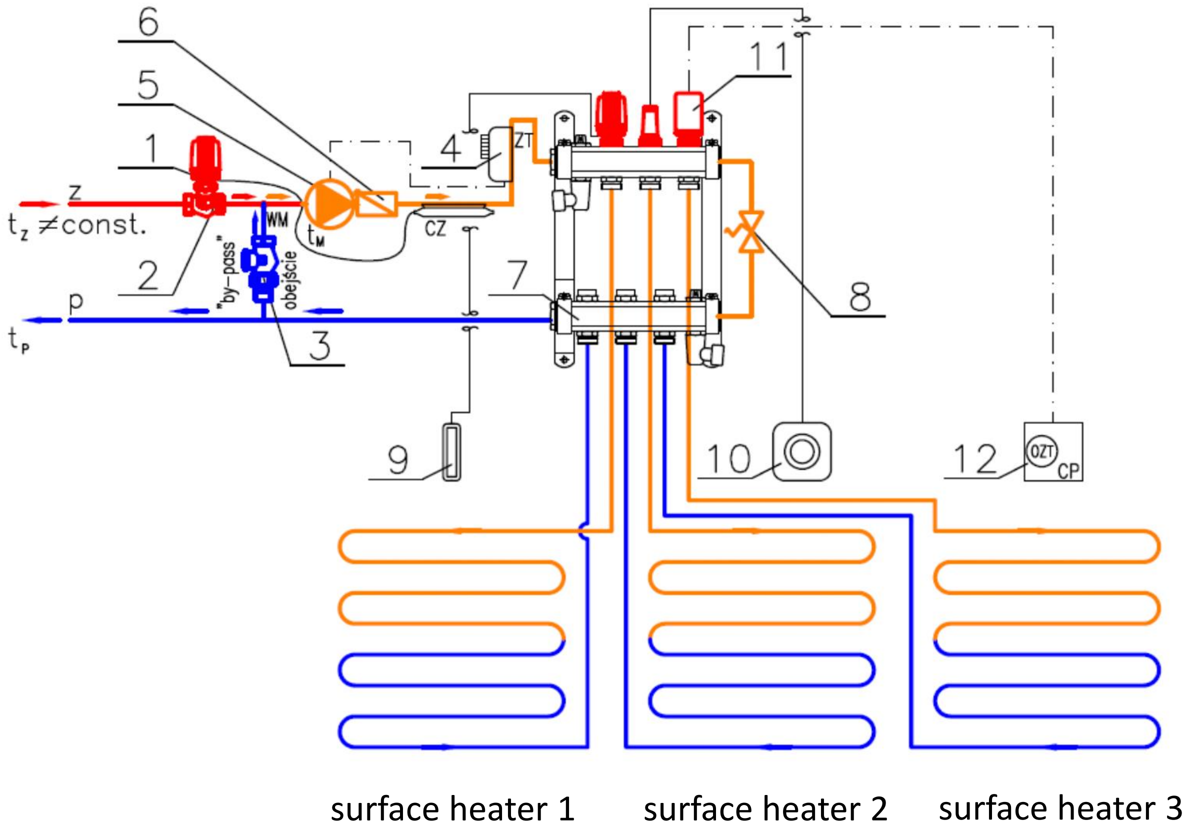
# Small building heating systems

## Installation layout

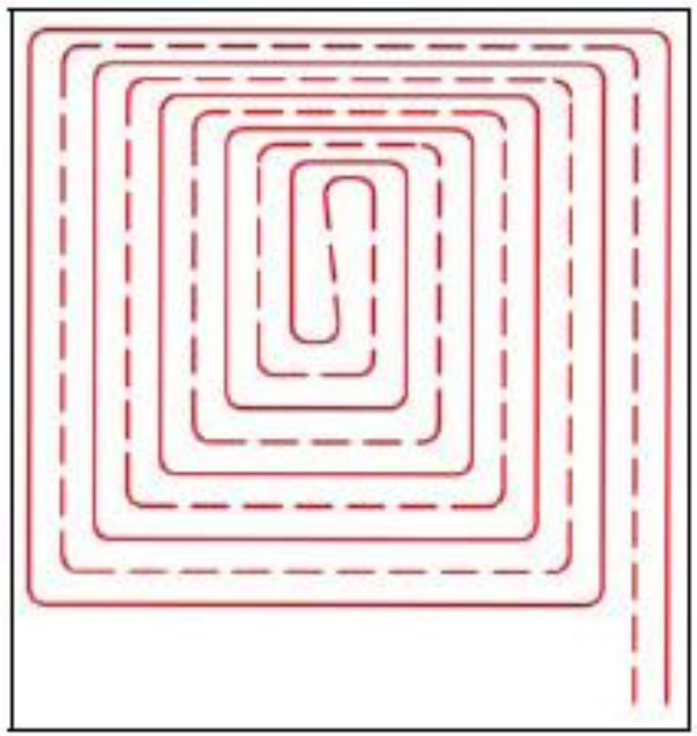


# Surface heating system with multiple loops

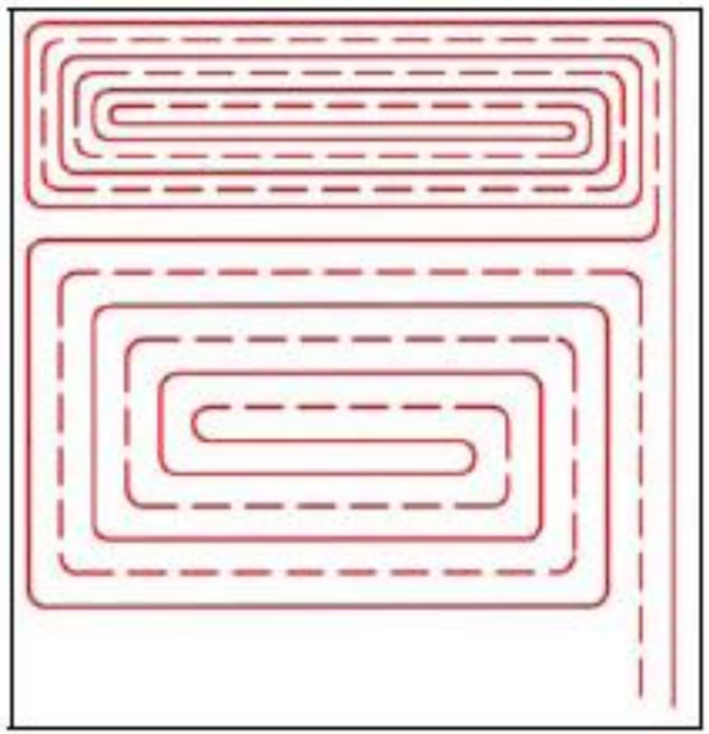
- protection system of surface heaters against overheating,
- temperature control system in individual rooms.



# Snail shape



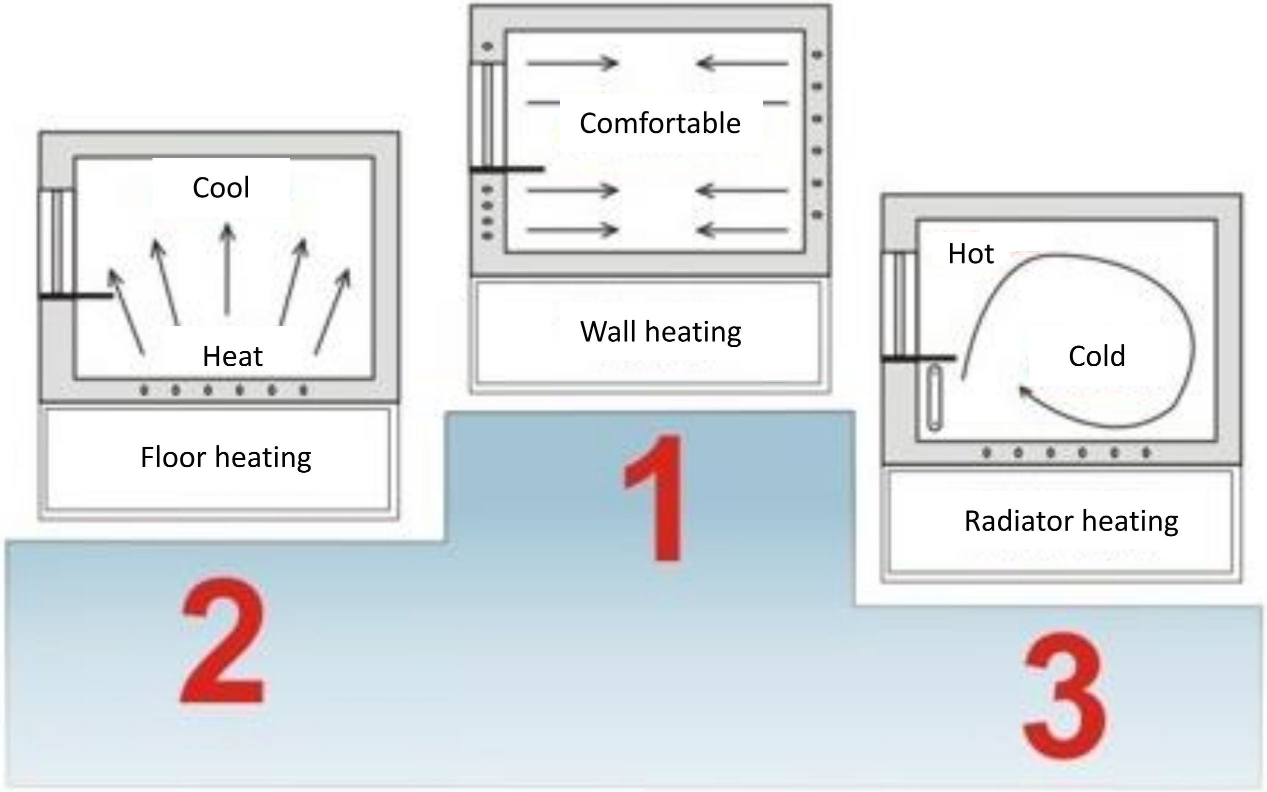
Form of coil worm (snail)with
integrated edge zone
with pipe compaction



Form of coil worm
with a separated edge zone

# Surface heating – wall

- water coils
- air channels
- wires, electric mats




*Source: parkiet.pl*

# Surface heating – wall

Water coils

*Source: paradigma.pl*

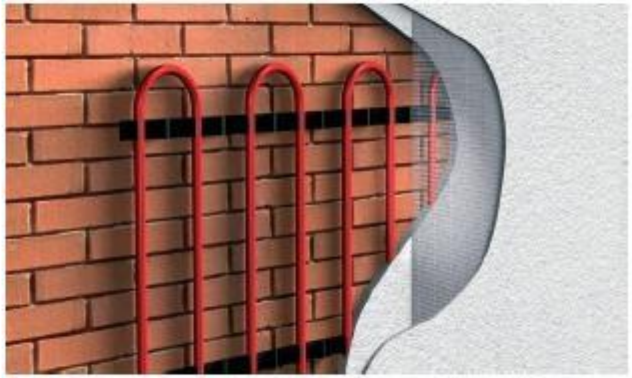
# Surface heating – wall
## Water coils

*Source: homla.pl*


*Source: kan-therm.pl*

# Surface heating – wall

## Water coils



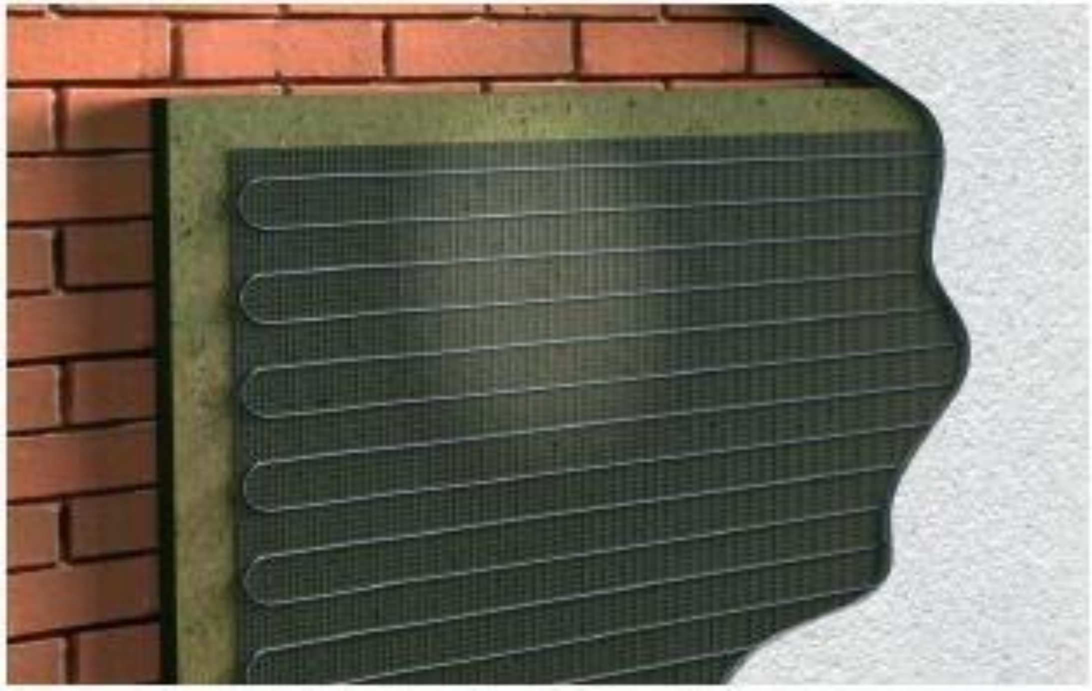
- a distance of 4 to 20 cm,
- appropriate assembly elements,
- for longer walls, especially above 10 m, dilatation is necessary.

Dilatations are also made between different types of building partitions – floor, ceiling and walls. The type and location of the dilatation must be specified in the design of the installation.

# Surface heating – wall

## Wires, electric mats

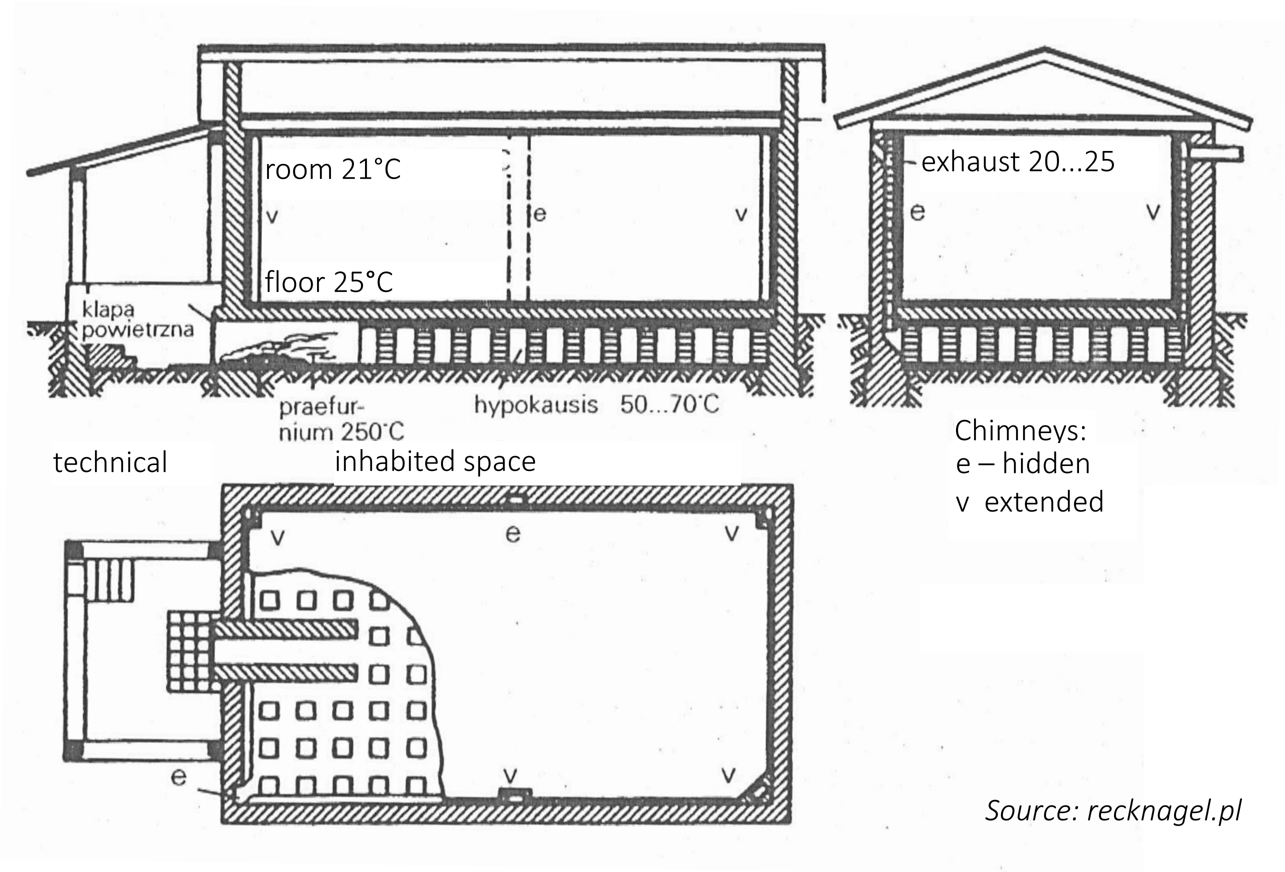
When furnishing the room, heating element placement must be considered!



Less thickness compared to the previously described technologies. It usually does not exceed 5–7 mm. As a consequence, it is associated with the need for a smaller total thickness of plaster to safely cover the heating installation.

# Surface heating – Floor air system

## Air ducts (hypokaustum)




*Source: recknagel.pl*

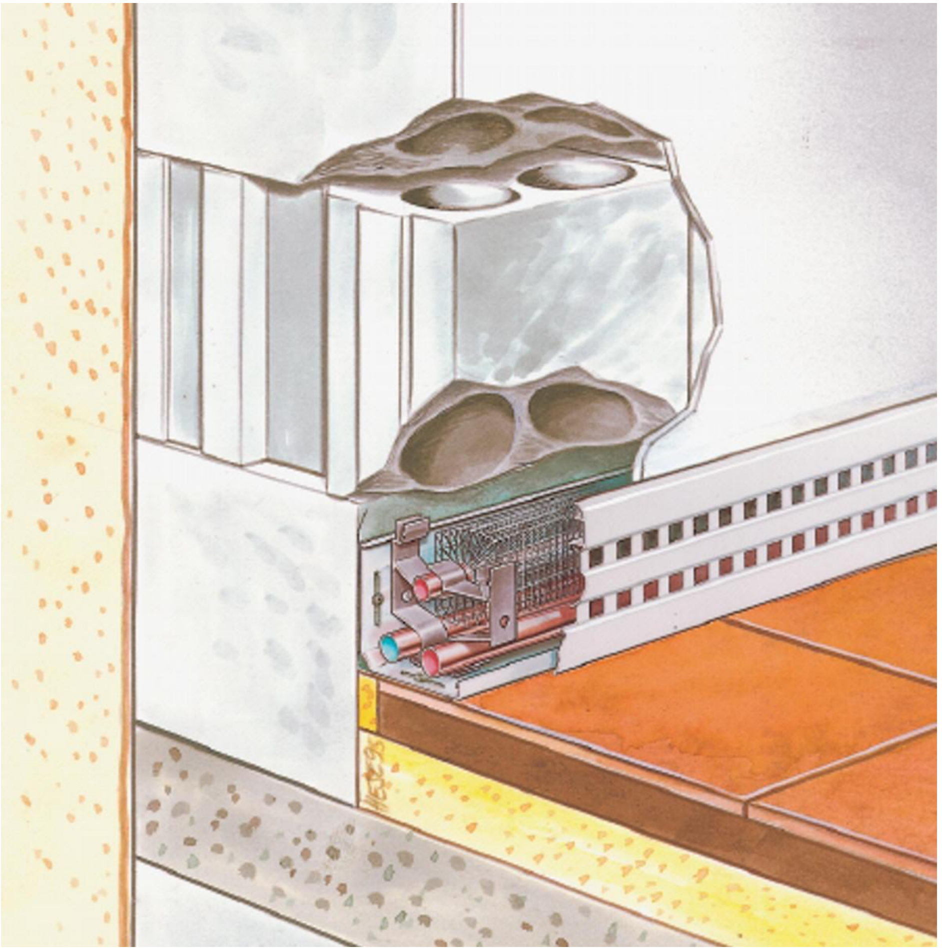
# Surface heating – Floor air system
## Air ducts (hypokaustum)

*Source: e-instalacje.pl*

# Surface heating – wall

## Air ducts (hypokaustum)

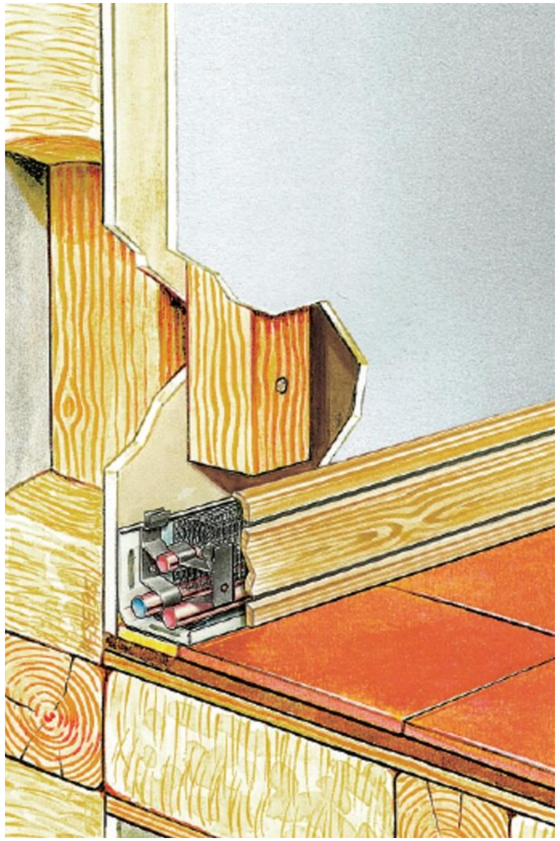
Reticular tube

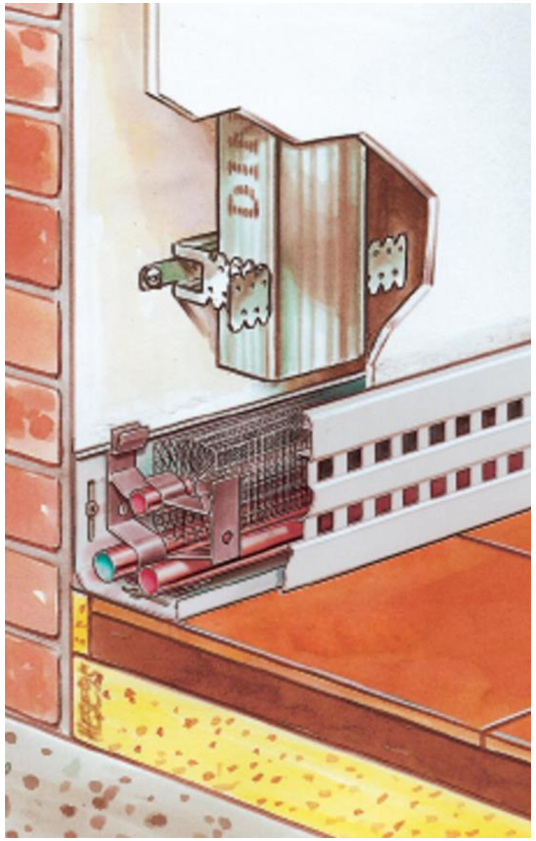


*Source: paradigma.pl*

# Surface heating – wall

## Air ducts (hypokaustum)





*Source: paradigma.pl*

# Surface heating – ceiling

capilary – type


coil – type

# Air heating system – advantages

Air heating can provide both effective heating and comfortable ventilation with filtration and air humidification, all within one system. There is one "common" installation, i.e. one investment. You can easily extend its functions with cooling, thus achieving full air conditioning throughout the year.

Air heating has a low inertia, thanks to which its efficiency adapts very quickly to the current heat demand. This means that heat is only supplied when it is actually needed, and this allows for some energy savings compared to traditional (water) heating systems.

The system can be turned off for a long time in winter without fear of freezing. Doing so with water heating systems is not possible.

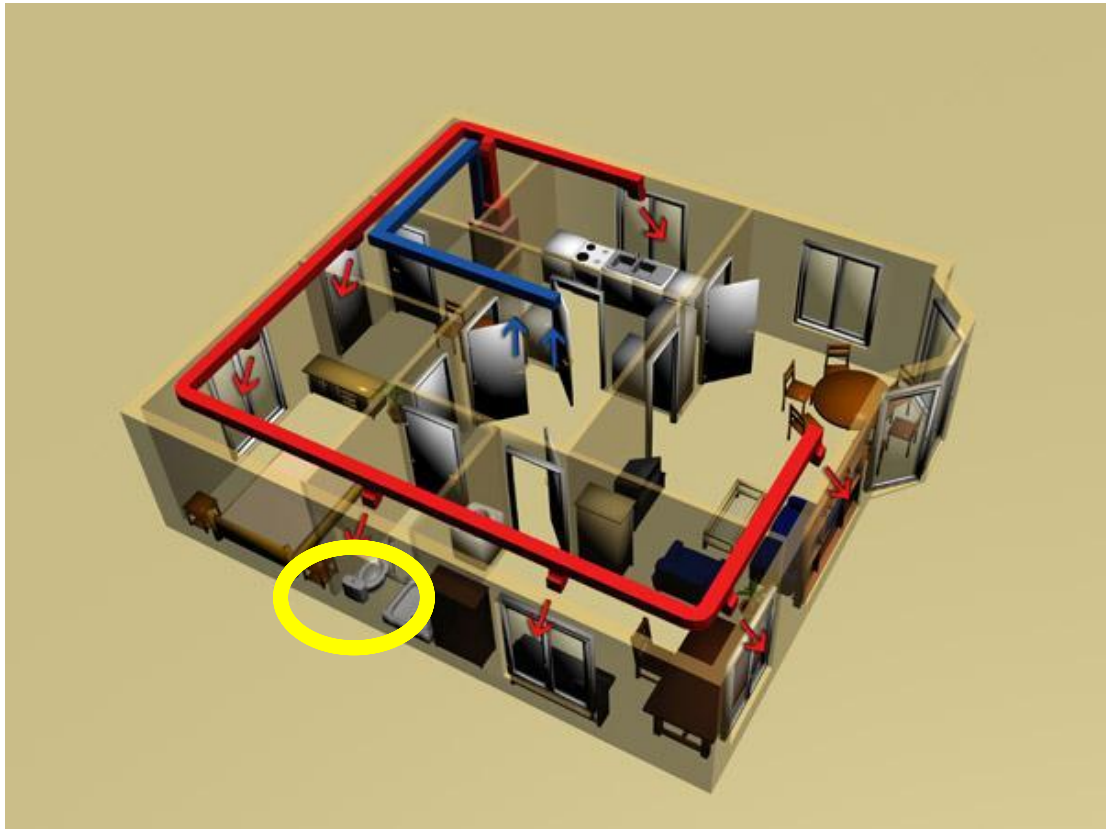
There is no risk of flooding the rooms with water if the heating system is unsealed.

Air heating is **more durable** than water. There is no danger of boiler scale and corrosion.

The elements of the installation transferring heat to the rooms (air supply grilles) do not take up space and do not disfigure (surface water heating – floor or wall – also has this advantage).

*Source: Kaźmierski, Murator 2007*

# Air heating system
## Flow control



*Source: elektroman.info*

# Air heating system

## Blowing furnace



The principle of the blast furnace operation. During combustion of the fuel in the combustion chamber (2) of the furnace, heat is produced. This energy is transferred to the exchanger (6) and heats the flowing air there. Warm air is distributed around the building using the main fan (5) and the duct system.
In the blast furnace, the combustion system is closed (7) – the flue gas does not mix with the heated air, but is thrown out by the exhaust fan (4) to the chimney or "through the wall". As a result, the air after heating can be directly blown into the rooms. The gas supply is controlled by a gas valve (3). A number of accessories are available for air-conditioning cabinets that improve comfort at home, e.g. air filter (1). The furnace can be installed in a vertical or horizontal position, it can also be easily hung up.

*Source: instsani.pl*

# Air heating system

*Source: murator.pl*

# Air heating system

*Source: wp.pl*

# Air heating system

*Source: heatec.pl*

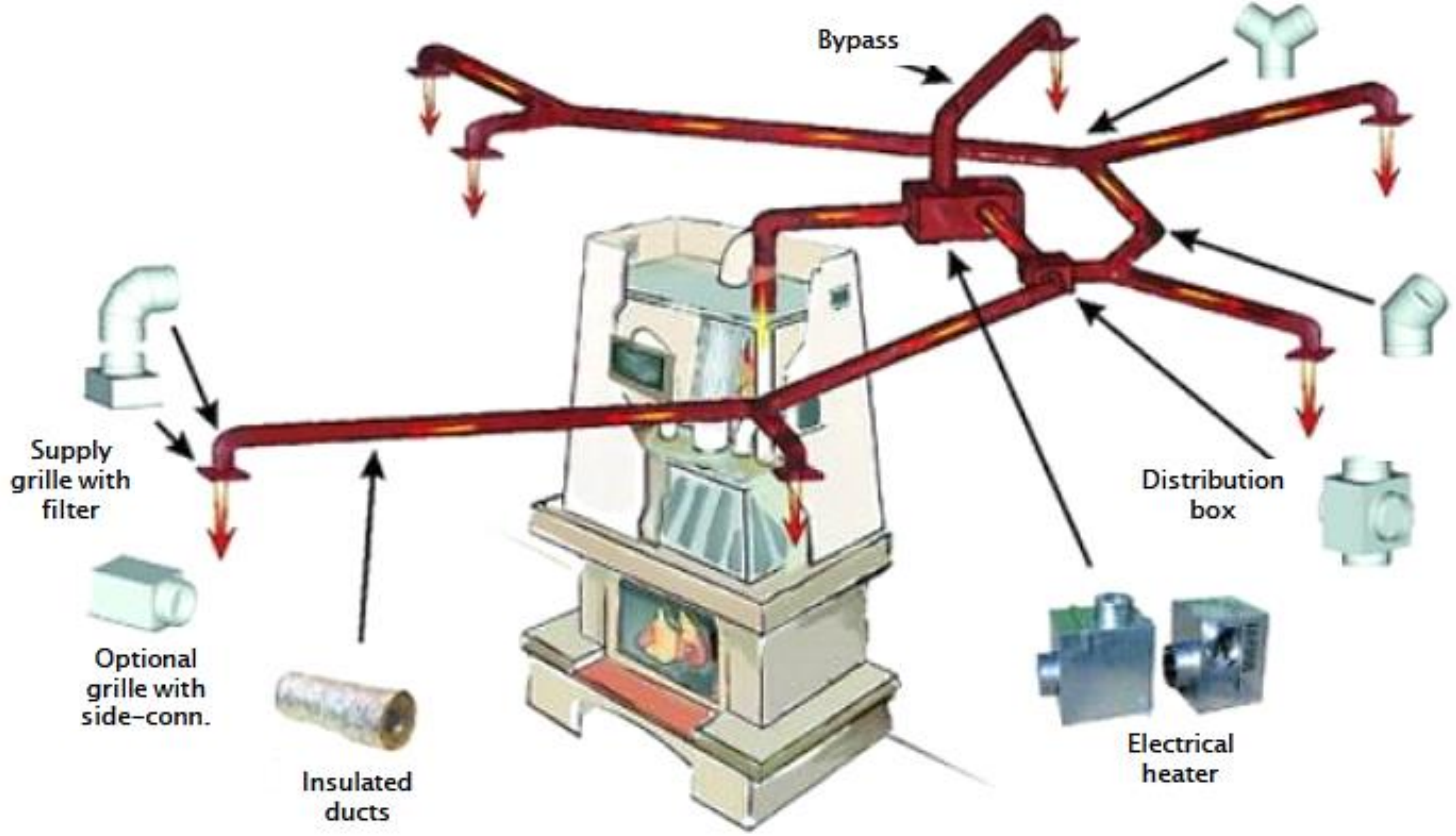
# Air heating system

*Source: heatec.pl*

# Air heating system

*Source: heatec.pl*

# Air heating system




*Source: Lis 2011*

# Air heating system

The above photograph shows a still uncovered foundation slab with the Legalett floor heating system installed. You can see on the photo a layer of insulation, formwork, plate reinforcement, as well as the ducts for air distribution.

In this solution, the air does not reach the room, but circulates in a closed circuit.

*Source: murator.pl*

# Air heating system – disadvantages

Transmission of heat through radiation is more natural – this is how the sun and fire warm us. Therefore, heating using the radiation phenomenon (radiator, floor, wall) is felt by the human being as more pleasant and more beneficial (no radiation).
In rooms where there is air heating, thermal comfort is achieved at a hygienic temperature, which is higher than in the case of heating by radiation. This results from two facts:

- **First of all** – the higher the air speed, the greater its cooling capacity. From the two streams of air at the same temperature, the colder one will felt as washing the human body when at a higher speed, so air has to be heated to a correspondingly higher temperature ($\nu = \Delta T_x + 8v_x$).

- **Secondly** – infrared radiation (occurring in radiation heating systems) is transformed into heat when it falls on a person or an object and heats it; a man warmed in this way will have the impression of thermal comfort despite the lower temperature of the surrounding air.

*Source: murator.pl*

# Air heating system – disadvantages

- Due to the higher (by design) temperature of air in rooms with air heating, heat losses through penetration through walls are higher than in rooms heated by radiation. Therefore, the partitions must have very good insulation.
- Intense air movements can cause the dust to rise and move.
- Air heating works louder than water heating systems.
- Blast heating ducts take up much more space than water heating pipes. More space in the walls and ceilings is needed to hide them.
- Rooms in which the heating works, quickly cool down in the event of possible failure of fans or power outages (floors, walls and furniture do not heat up, because there is no radiation phenomenon).

*Source: murator.pl*

# Air distribution


*Source: geberit.pl*

# Air distribution

*Source: geberit.pl*

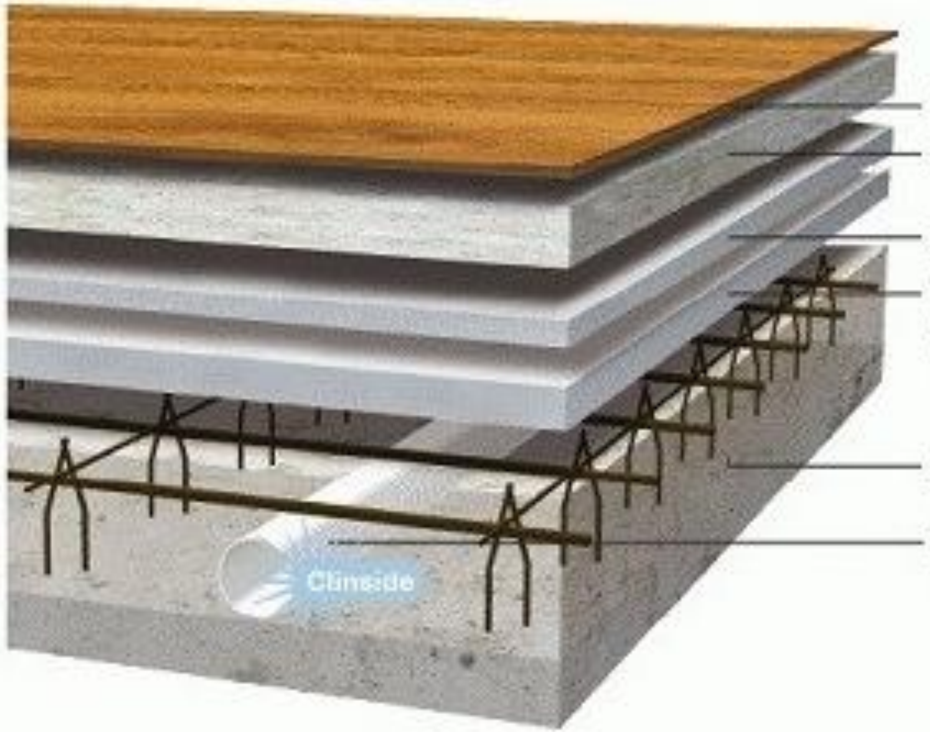
# Air distribution

## Zehnder System In Floor

Zehnder InFloor is a system of round ventilation ducts, plenum boxes, distributors, as well as additional parts that enable the construction of any mechanical ventilation system. The InFloor system can be easily masked in screeds, ceilings, as well as under dry and wet plasters. The InFloor system offers three channel diameters: 63 mm, 75 mm and 90 mm – this is definitely a great convenience when constructing the best home installation.

# Air distribution

Zehnder InFloor
Installations in concrete



# Air distribution

Advantages of the Zehnder InFloor system:

- low weight with the simultaneous stiffness of Zehnder InFloor ducting, gives the possibility of placing them in the ceiling or in grout,
- the connections on the EPDM gaskets ensure tightness of connections regardless of the conditions,
- three InFloor channel diameters (63/75/90 mm) allow for the selection and assembly of the most suitable installation,
- antistatic, antifungal and antibacterial layers provide the required purity of the system during operation and guarantee the hygiene of the transported air,
- the best acoustic and insulating qualities are on offer; duct placement is carried out by way of the shortest possible route to avoid sudden changes in the air direction,
- the installation technique ensures low pressure losses when in operation; all necessary connections and accessories are included,
- extremely easy to keep clean,
- a large selection of ceiling and wall supply and exhaust grates are available.

# Air distribution
## Zehnder System On Floor

Zehnder OnFloor is a system of oval ventilation ducts, plenum boxes, distributors and additional elements enabling the construction of any supply-exhaust ventilation system. OnFloor is very easy to place in screeds, ceilings and under dry and wet plasters. The height of the channel is only 50 mm, which allows for a greater range of placements.

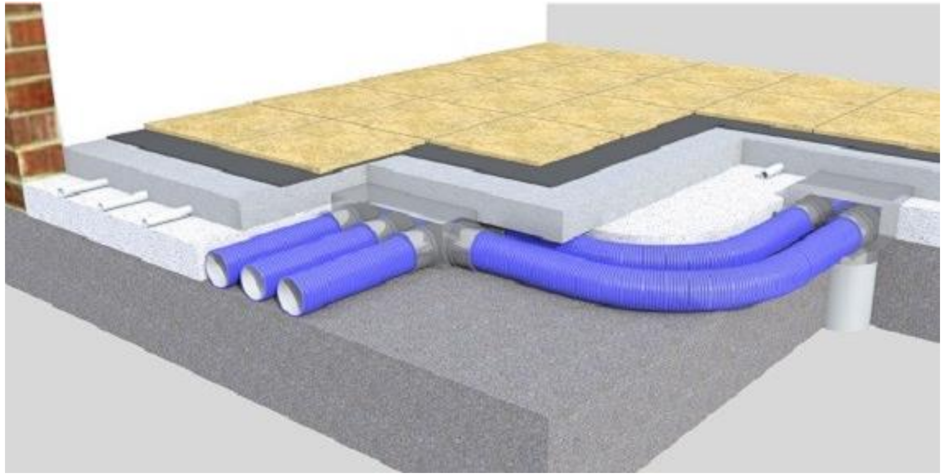
# Air distribution

**Advantages of the Zehnder OnFloor system:**

- low weight and high rigidity of the ductwork give the possibility of placing them in the ceiling or in grout,
- EPDM gaskets ensures high tightness of connections in all conditions,
- height of the channel only 50 mm, giving the possibility of a greater range of placements,
- antifungal, antibacterial and antistatic coatings keep the system clean during operation, as well as ensure high hygiene of the air being blown,
- the system has excellent acoustic and insulating properties,
- ventilation ducts can be routed in the shortest way to minimize the risk of unexpected changes in air direction,
- the pipes are placed in such a way as to reduce pressure losses when in operation,
- the set includes all connectors and accessories,
- the system is very easy to clean,
- a very large selection of supply and exhaust grates for walls and ceilings is available.

# Air distribution
## Ventiflex system

Ventiflex is a ventilation duct system of expansion boxes, distributors and additional elements enabling the construction of any supply-exhaust ventilation system in an extremely simple way. It can be hidden in the scree, in ceilings and under dry and wet plasters.



# Air distribution

**Advantages of the Ventiflex system:**

- small size, the rigidity of Ventiflex® ductwork makes it is possible to place them in walls or in the scree layer; the use of EPDM gaskets ensures tightness in all conditions,
- the small diameter of Ventiflex ducts (75 mm) allows installation under dry plaster and paneling,
- antistatic, antibacterial and antifungal coatings keep the system clean; the system has enhanced insulation and acoustic properties,
- The ductwork can be routed as short as possible to minimize the risk of unexpected changes in air direction,
- the technique of placing the ducts ensures low pressure loss, all necessary accessories and connectors are easy to clean.

# Air distribution
## Vasco system

The EASYFLOW system has been designed for the needs of single-family homes and can work with any recuperator. All elements of the pipe system have built-in gaskets and are supplied with the necessary assembly clamps. In addition, the system favors efficient installation and allows the installation to be carried out reliably every time. The EASYFLOW channels are telescopically connected without the need for special tools.

# Air distribution

Advantages of the Vasco system:

- of little weight, the rigidity of Vasco ducts allows them to be placed in the ceiling or in the scree layer; the used EPDM gaskets ensure tightness of connections regardless of the conditions,
- the small diameter of Vasco ducts (60 mm) gives the possibility of installing each element under dry plaster, or paneling,
- the anti-static coating helps keep the system clean, and increases acoustic and insulating properties,
- ventilation ducts can be routed in the shortest way to minimize the risk of unexpected changes in the direction of air flow (bends, too sharp arcs),
- the method of arrangement of the ducts ensures low pressure losses; the set includes all necessary connectors and accessories and allows for uncomplicated cleaning.
- Its most important advantage is the height of the channel, which is only 60 mm, which ensures minimal problem in installation in every building regardless of its construction and applied wall and ceiling technology.
- the Eastflow system can be successfully installed remedially in inhabited buildings – such a task is usually very difficult.

# Air distribution

*Source: zehnder.pl*

# Air distribution

*Source: reku.net.pl*

# Air distribution

*Source: reku.net.pl*

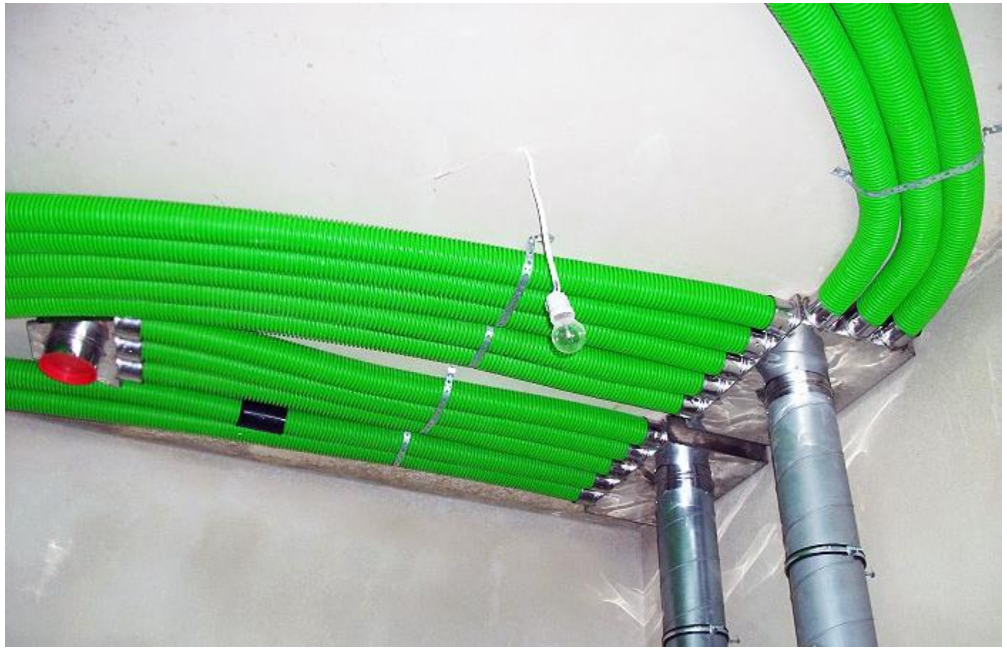
# Air distribution

*Source: reku.net.pl*

# Air distribution

*Source: reku.net.pl*

# Air distribution



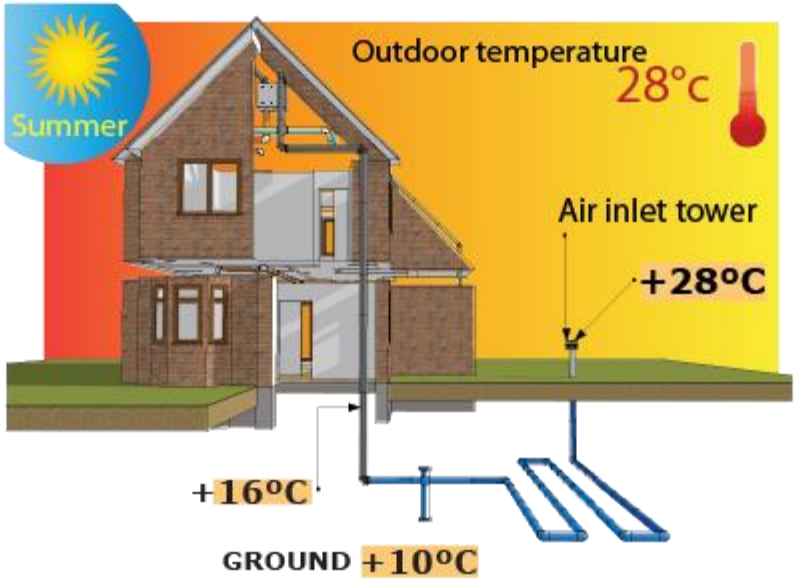
*Source: reku.net.pl*

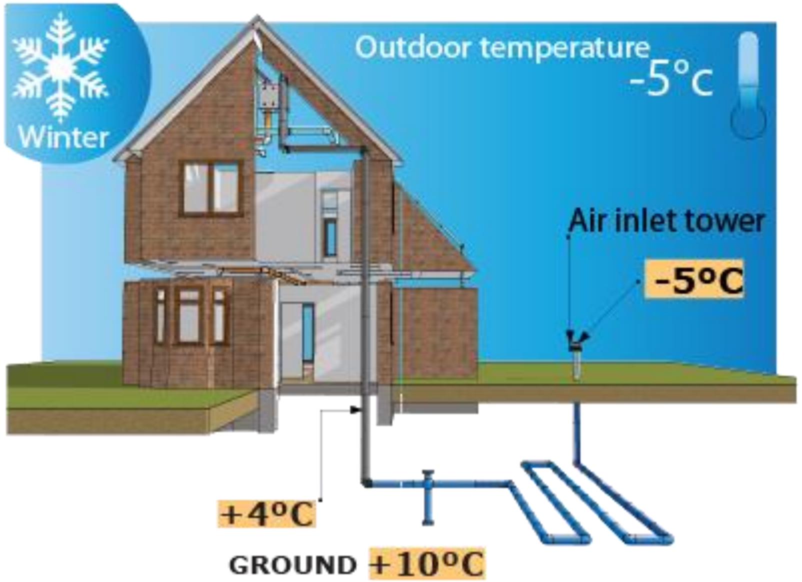
# Air distribution

*Source: reku.net.pl*

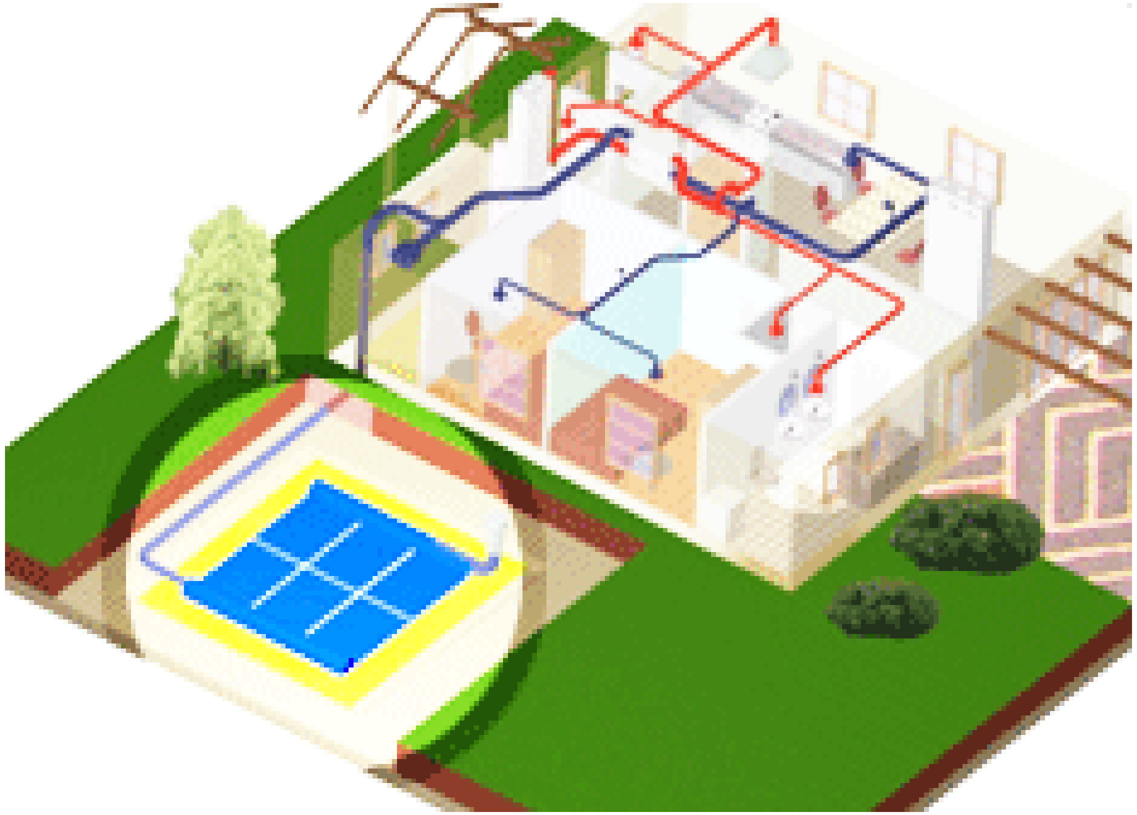
# Ground – air heat exchangers

There are two basic construction types of ground heat exchangers:
1) direct ground heat and mass exchangers
2) indirect heat exchangers.



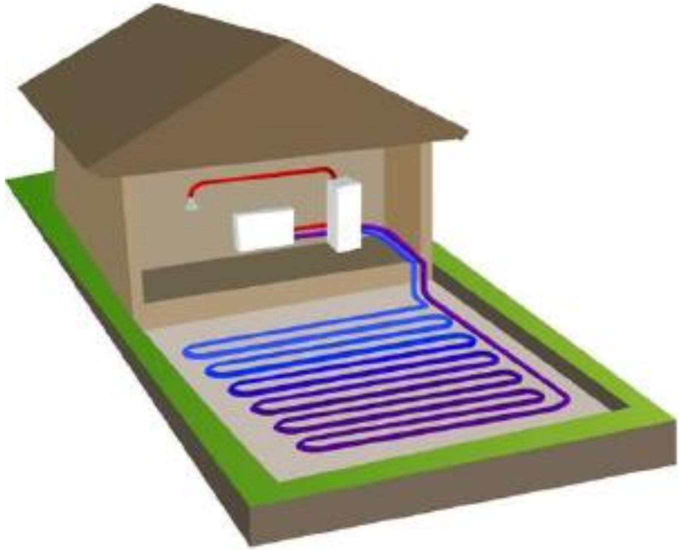



# Ground – air heat exchanger

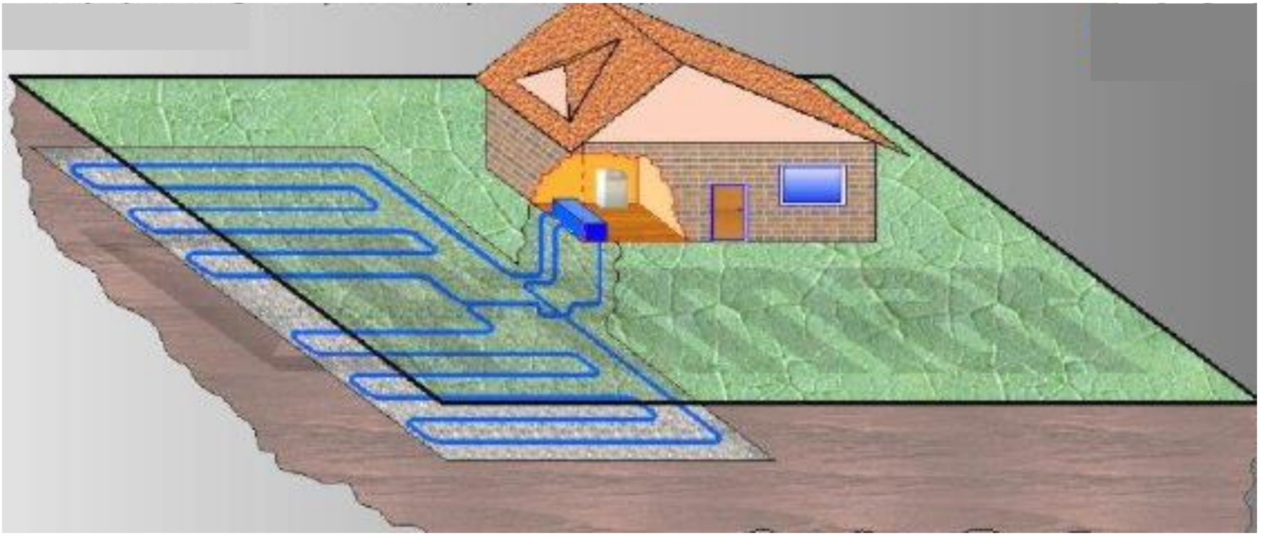


*Source: pro-vent.pl*

# Ground source



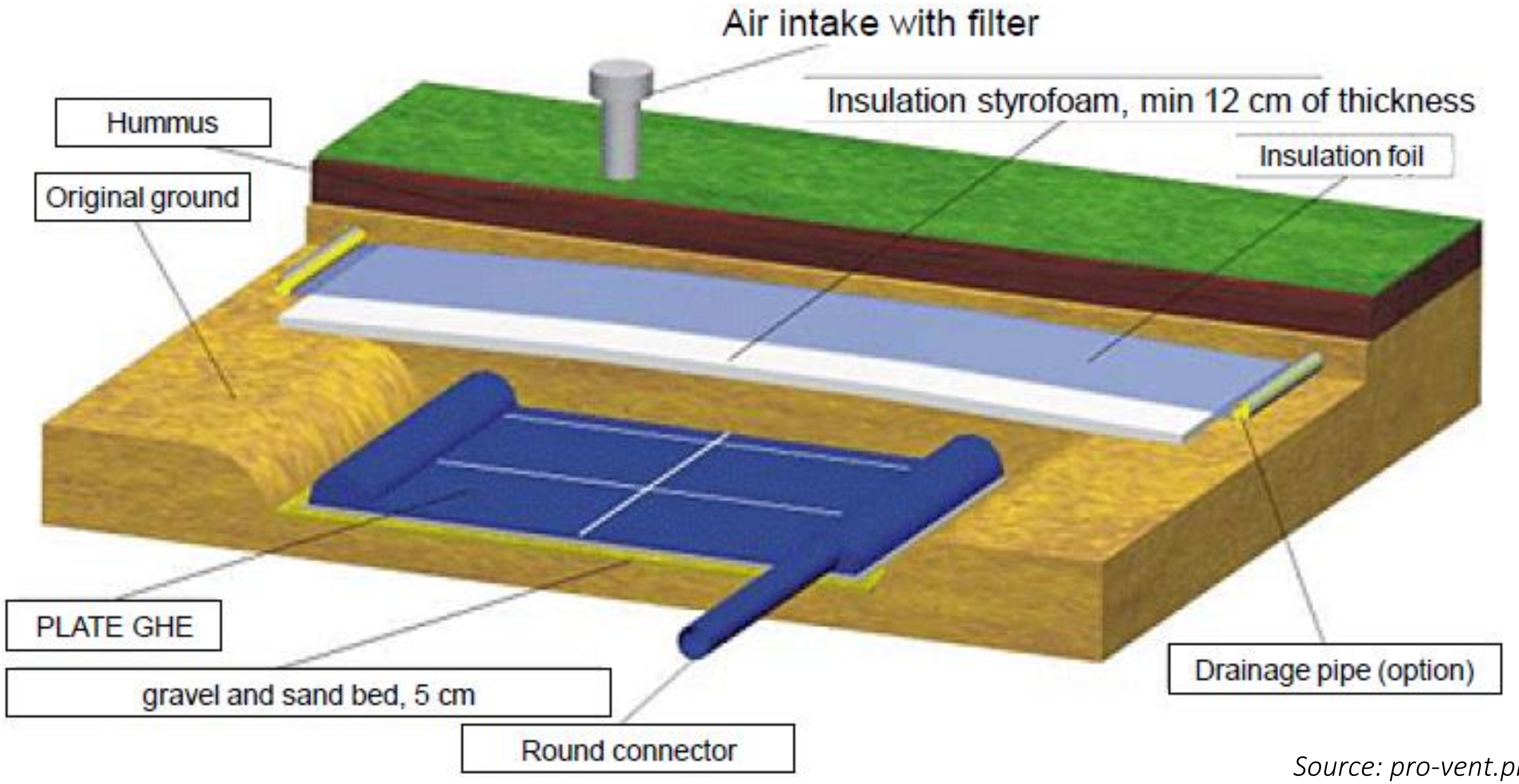
Source: *thermogolv.pl*



Source: *pamar.waw.pl*

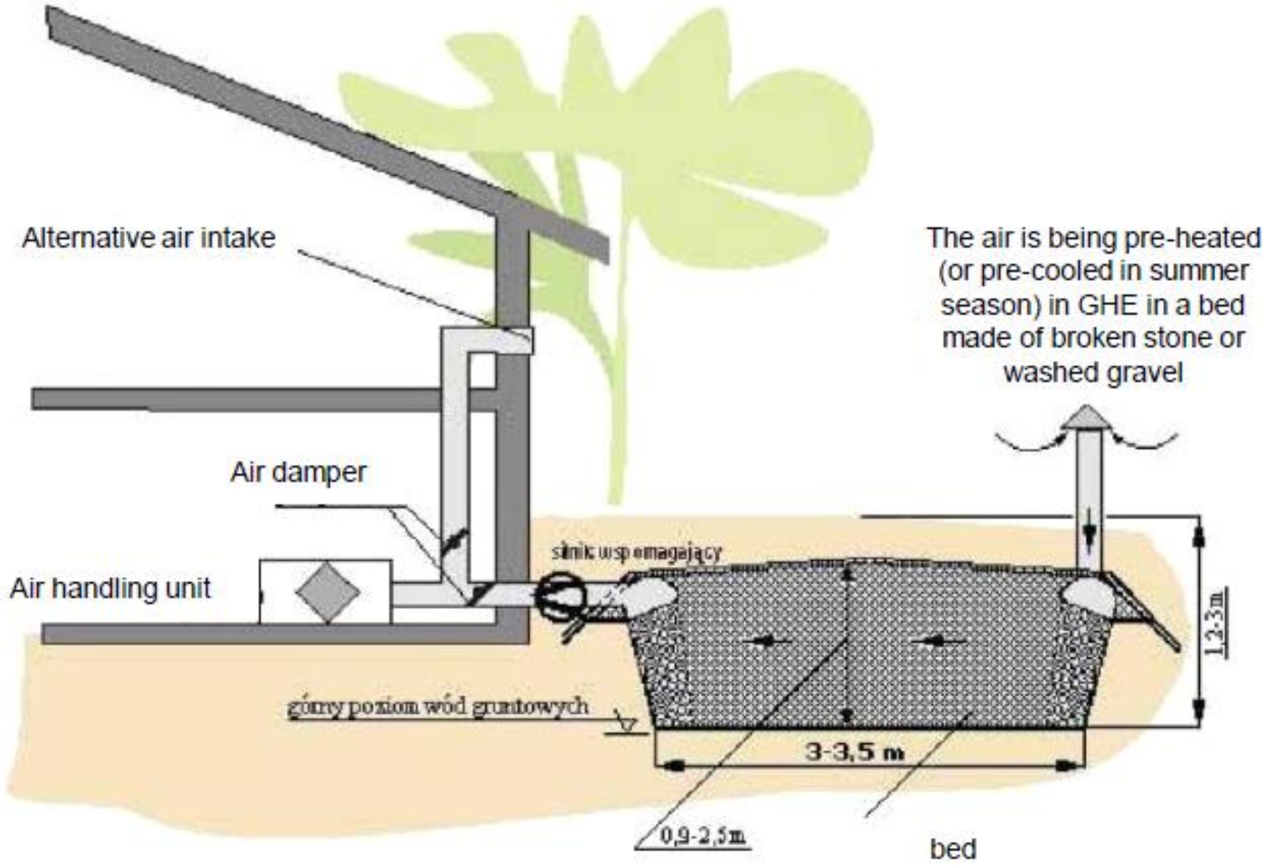
# Ground source heat exchanger

## Cross – section of provent – geo heat exchanger



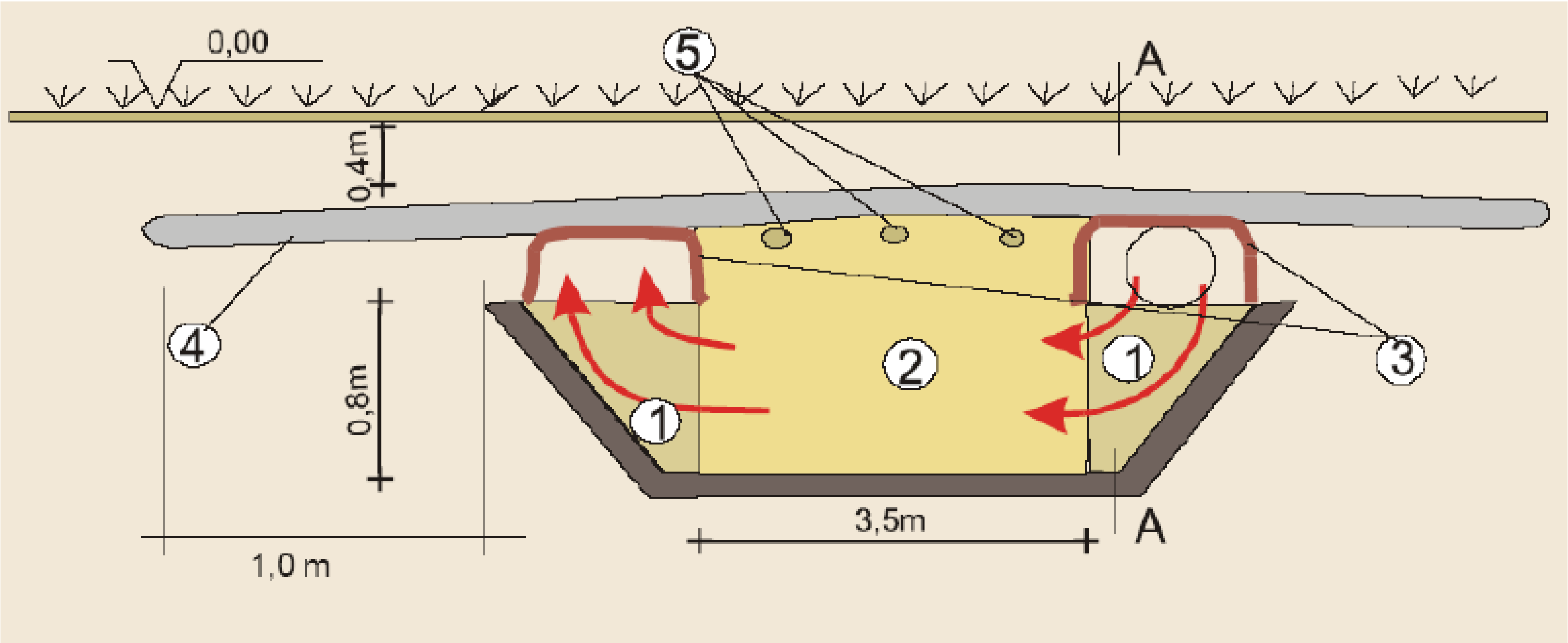

*Source: pro-vent.pl*

# Ground source – air heat exchanger




*Source: instalacje.pl*

# Ground source heat exchanger – gravel

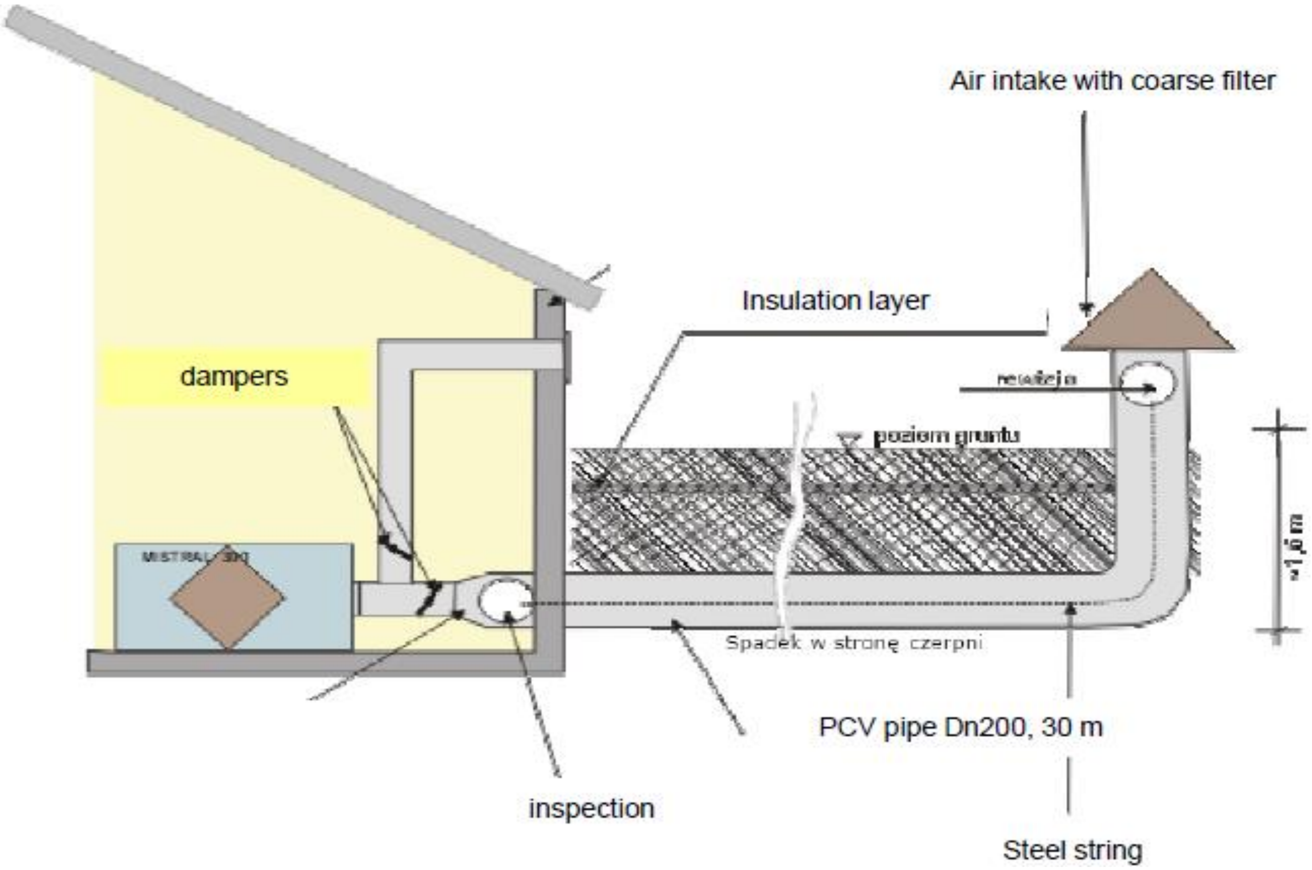



1. Granulated stone 60 – 90 mm
2. Gravel 30 – 50 mm
3. Concrete bed
4. Insulation 10 cm
5. Spray tubes

**Watch for Radon!**

*Source: instalacje.pl*

# Ground source heat exchanger – pipe




*Source: instalacje.pl*

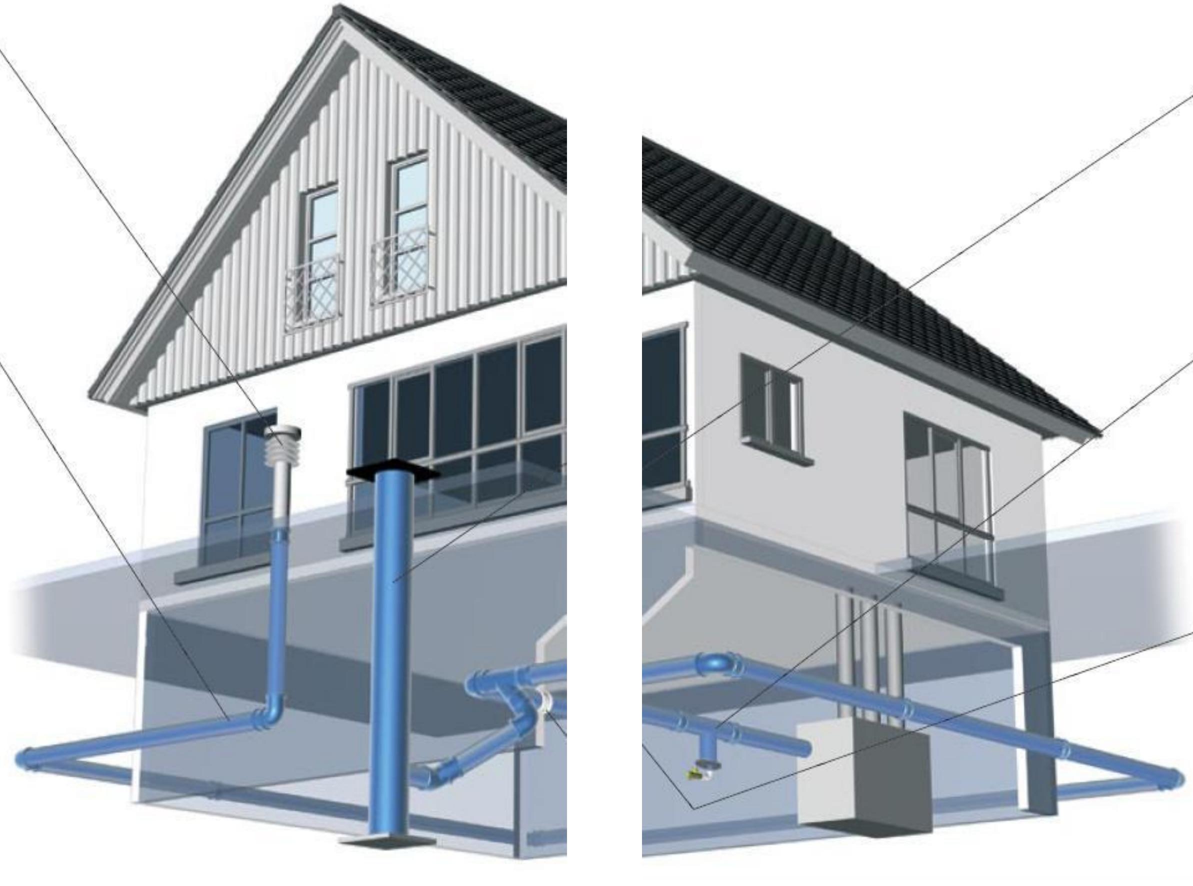
# Ground – air heat exchanger

## Pipe – type

**1. Air intake with filter**

**2. Aquaduct Thermo system**

- full-wall polypropylene pipe
- antibacteial inner layer
- high longitudinal stiffness
- Radon – protected (reliable seals)

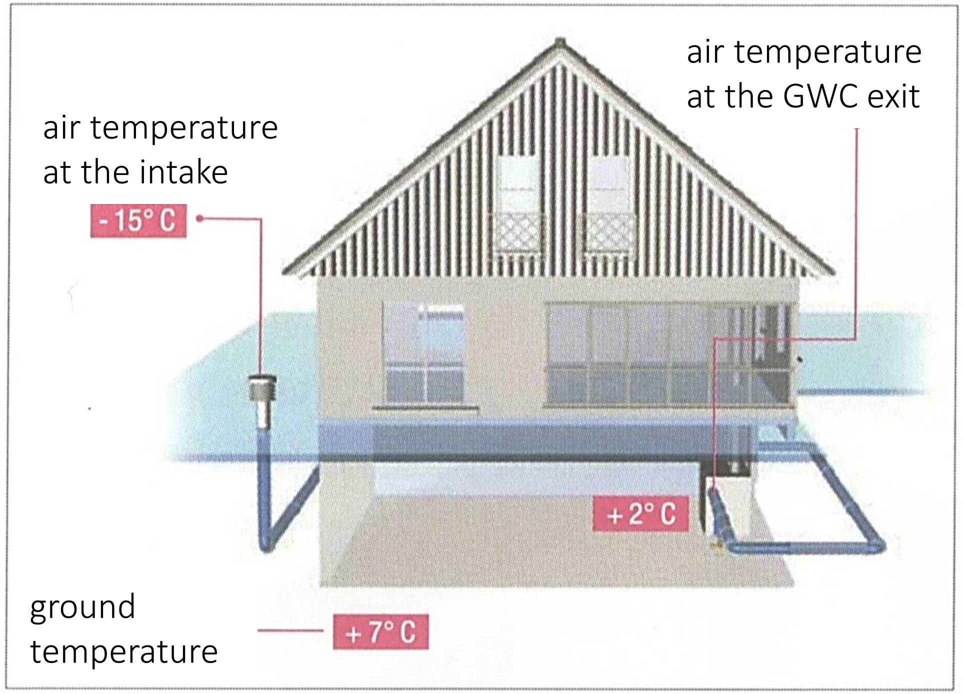


3. Drain
3.1. buildings without a basement – by drainage pit

3.2. buildings with a basement – by ball siphon with connection to the internal sewage system

**4. Sealed passage**

# Ground – air heat exchanger – pipe-type



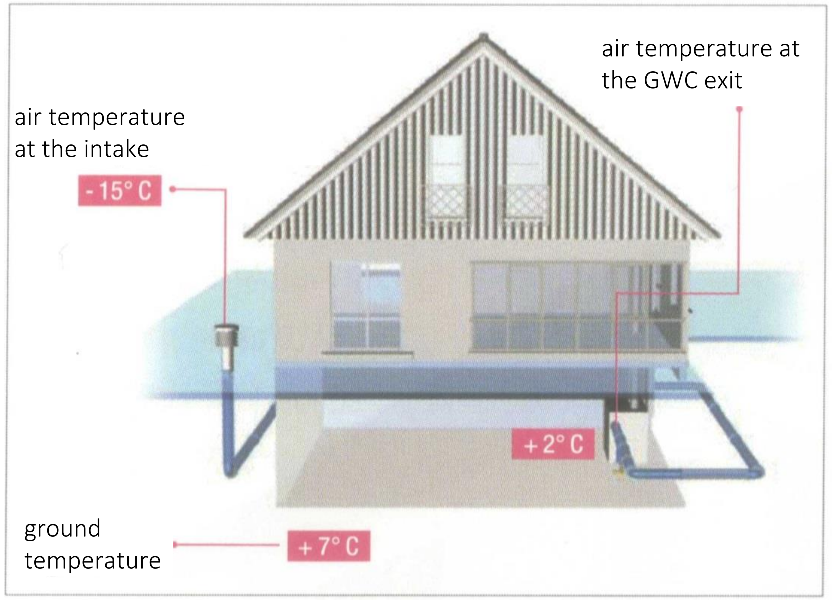

Air velocity 1 m/s
Diameter Dn 200
Air flow 120 $m^3$/h

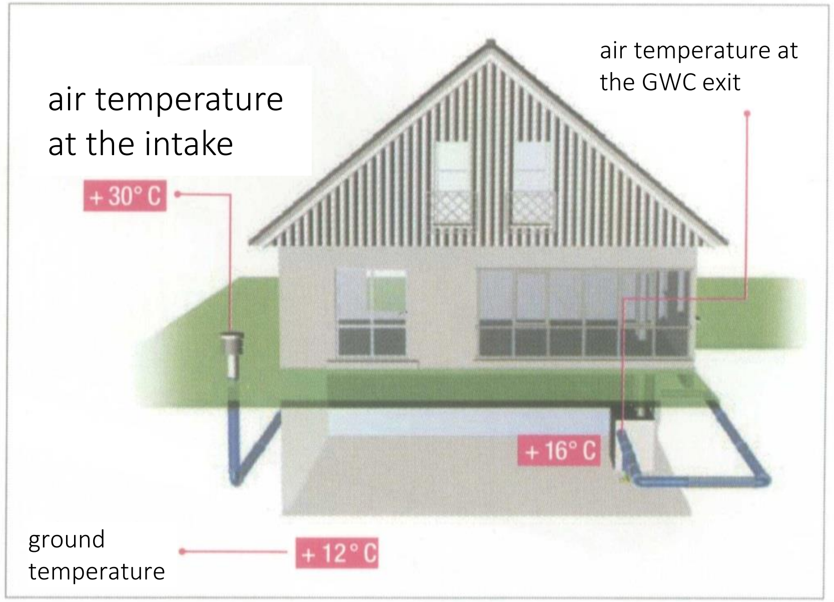
Heat flux 680 W
Lenght 70 m
Effect 10 W/mb
The cost of heat from a gas boiler
Boiler GZ50 efficiency 90%
K = 0.176 zł/kWh
The amount of heat in the heating season
K = 31.0 kWh/($m^3$/h)

$G = m*c_p*Dt*5{,}000$ h
= 0.04*1.005*17*5,328 = **3,641 kWh**
G*price = 3,641*0.176 zł/kWh = **640 zł/season**
Cost of HX 15,000 zł
Payback time. **23.5 years**

# Ground – air heat exchanger

## Pipe – type




Air velocity 1 m/s
Diameter Dn 200
Air flow 120 $m^3$/h

Summer operation only
Compared to a split system, payback time is 27 years.

# Ground – air heat exchanger

# Ground – air heat exchanger

*Source: instalacjebudowlane.pl*

# Design

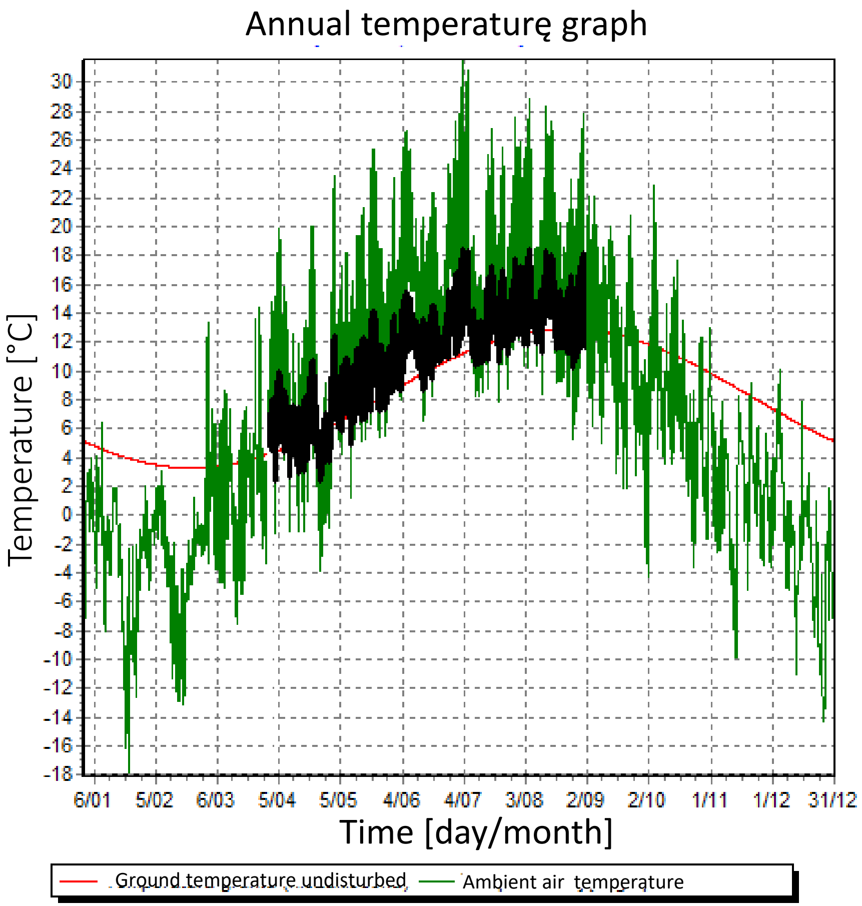
REHAU

Exit temperature calculations

Start calculations

**Results:**
**Cooling mode**

| | |
|---|---|
| **Max outlet temperaturę [°C]:** | 18.5 |
| Heat supplied [kWh/a]: | 1 167.1 |
| Heat rejected [kWh/a]: | 12 802.7 |
| **Cooling netto [kWh/a]:** | 13 635.6 |
| **Air velocity [m/s]:** | 1.9 |
| Pressure drop [Pa]: | 69.1 |
| Annual working time | [–]: 8.12 |



# Part 5

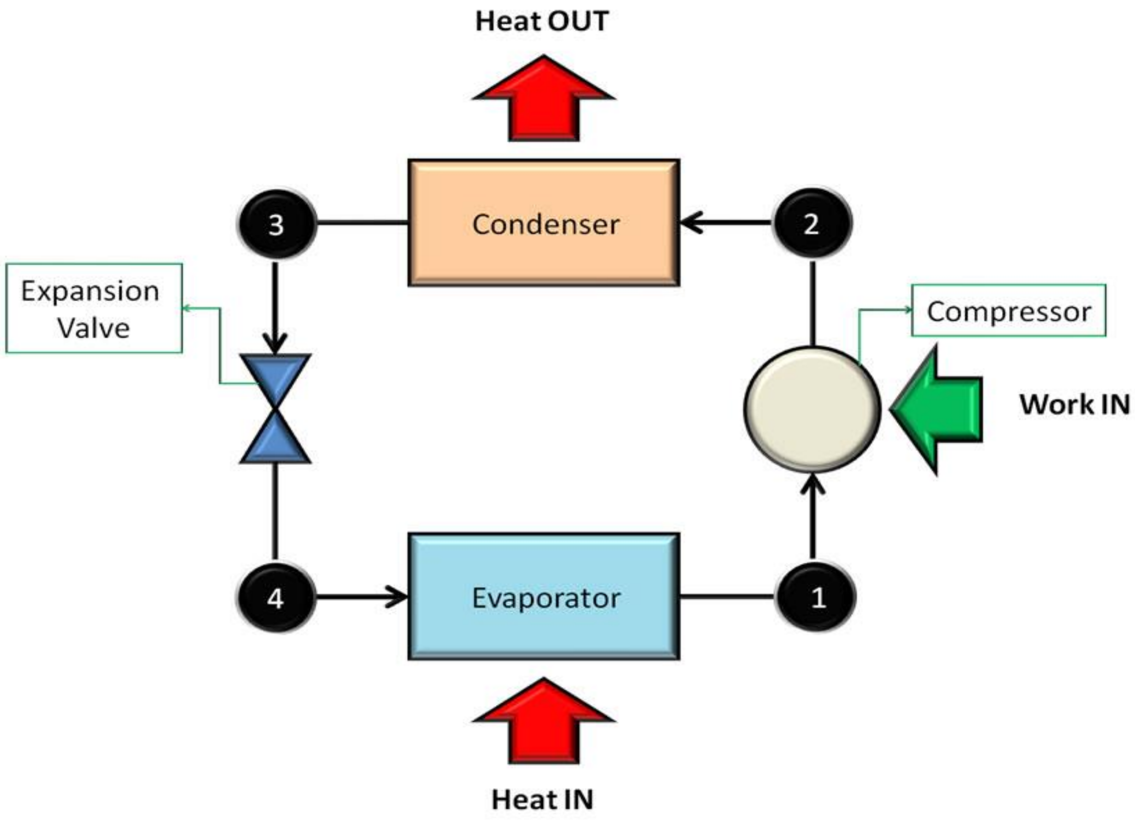
# *Alternative system*

*Jarosław Müller*

# OUTLINE OF THIS PART:

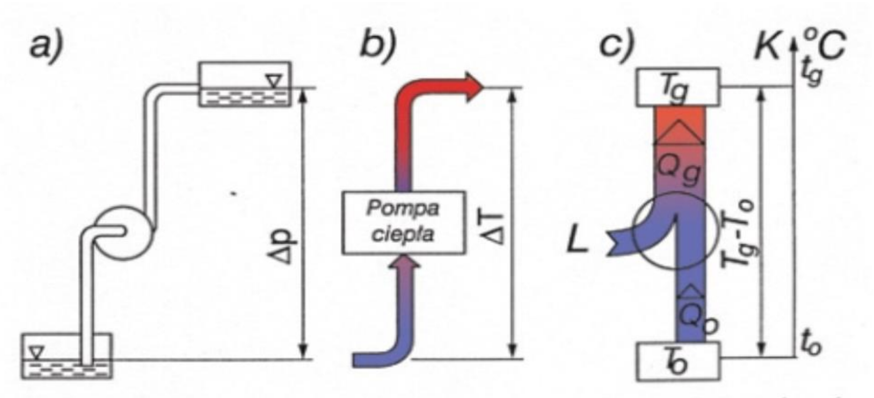
- Heat pumps
- Geothermal systems
- Solar systems
- PV panels
- Wind turbines

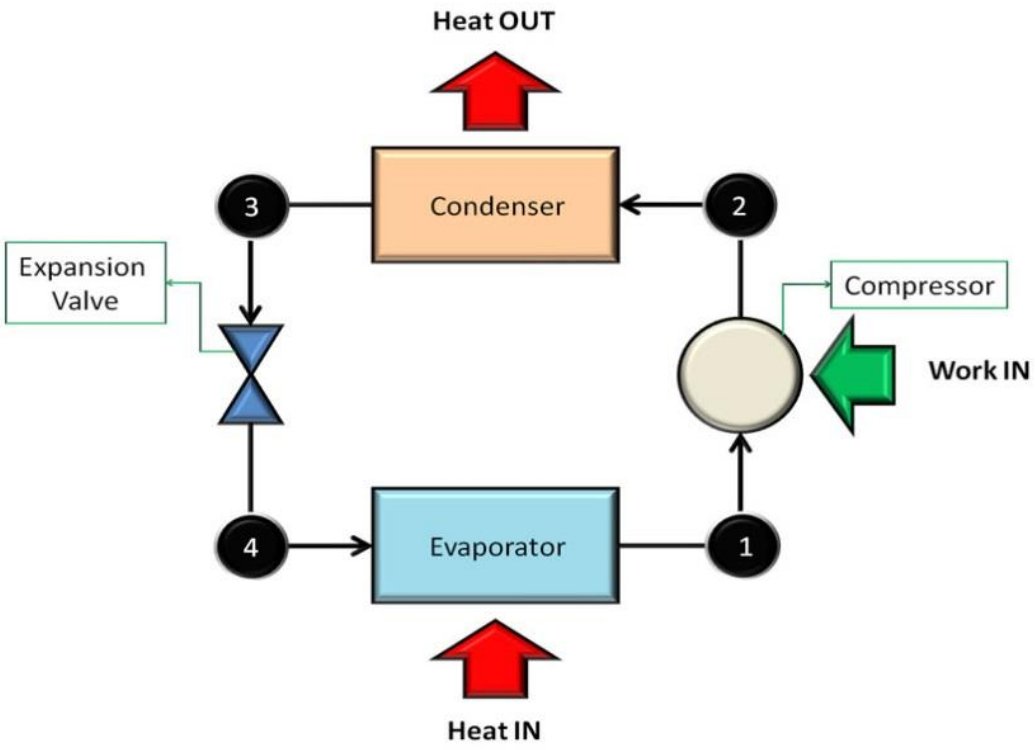
# Heat pumps




Vapor compression cycle
(left-driven refrigeration cycle)

# Heat pumps


a)
b)
c)
Pompa ciepła
Δp
ΔT
K
°C
L


Heat OUT
Condenser
Expansion Valve
Compressor
Work IN
Evaporator
Heat IN
1
2
3
4

# Heat pumps


horizontal heat exchanger
1
2
3
4
internal installation
vertical heat exchanger

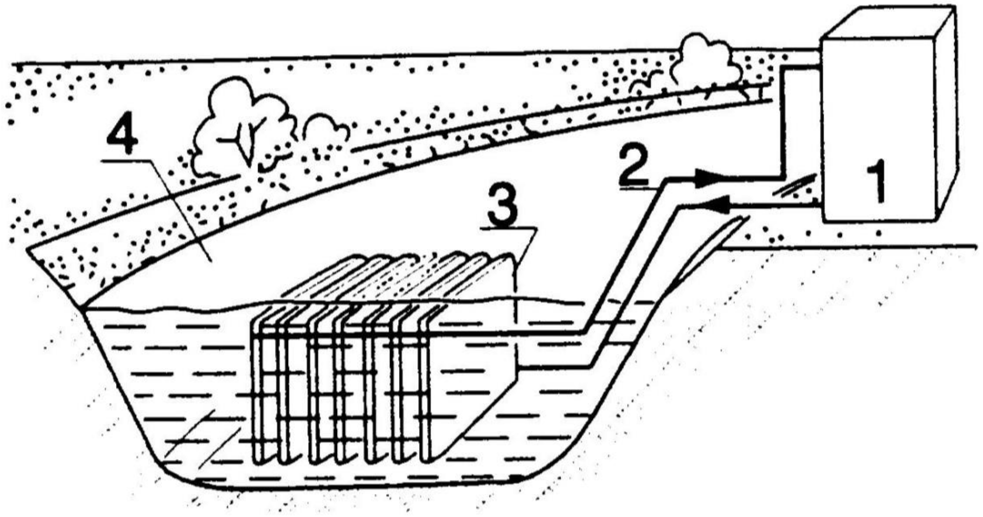
# Heat sources for heat pumps
## Atmospheric air

- easy available, low investment cost
- non-coherent
- large, noisy heat exchangers
- frost build-up

# Heat sources for heat pumps

## Surface water

- easy available, low investment cost
- non-coherent
- unstable temperature
- frost build-up

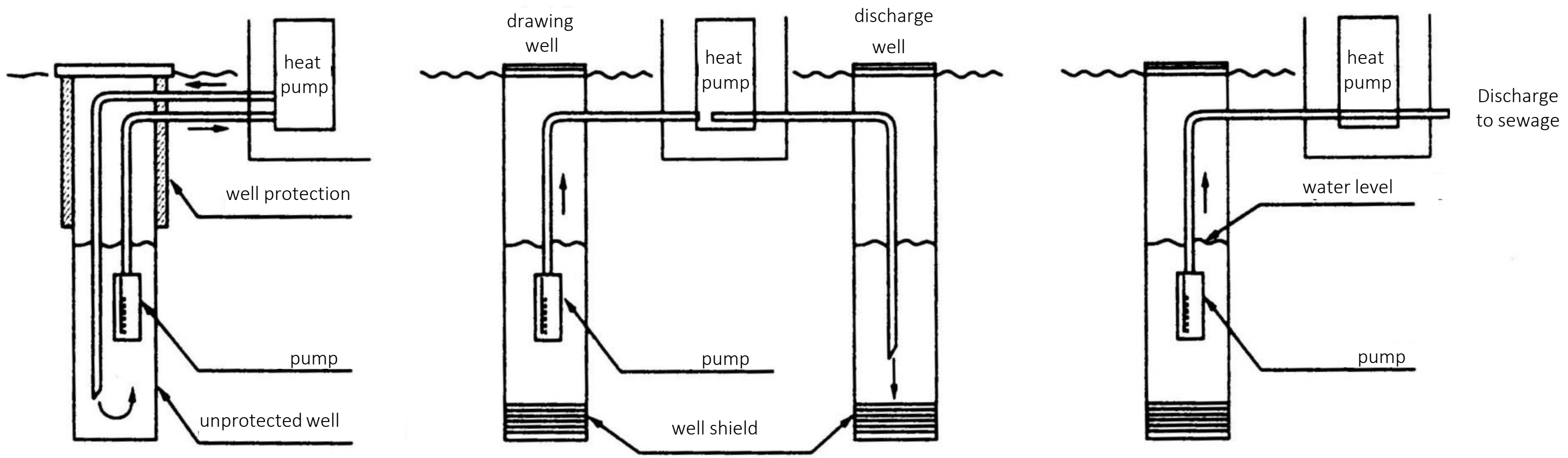



1 – heat pump
2 – piping
3 – heat exchanger
4 – surface water (river)

# Heat sources for heat pumps

## Ground water

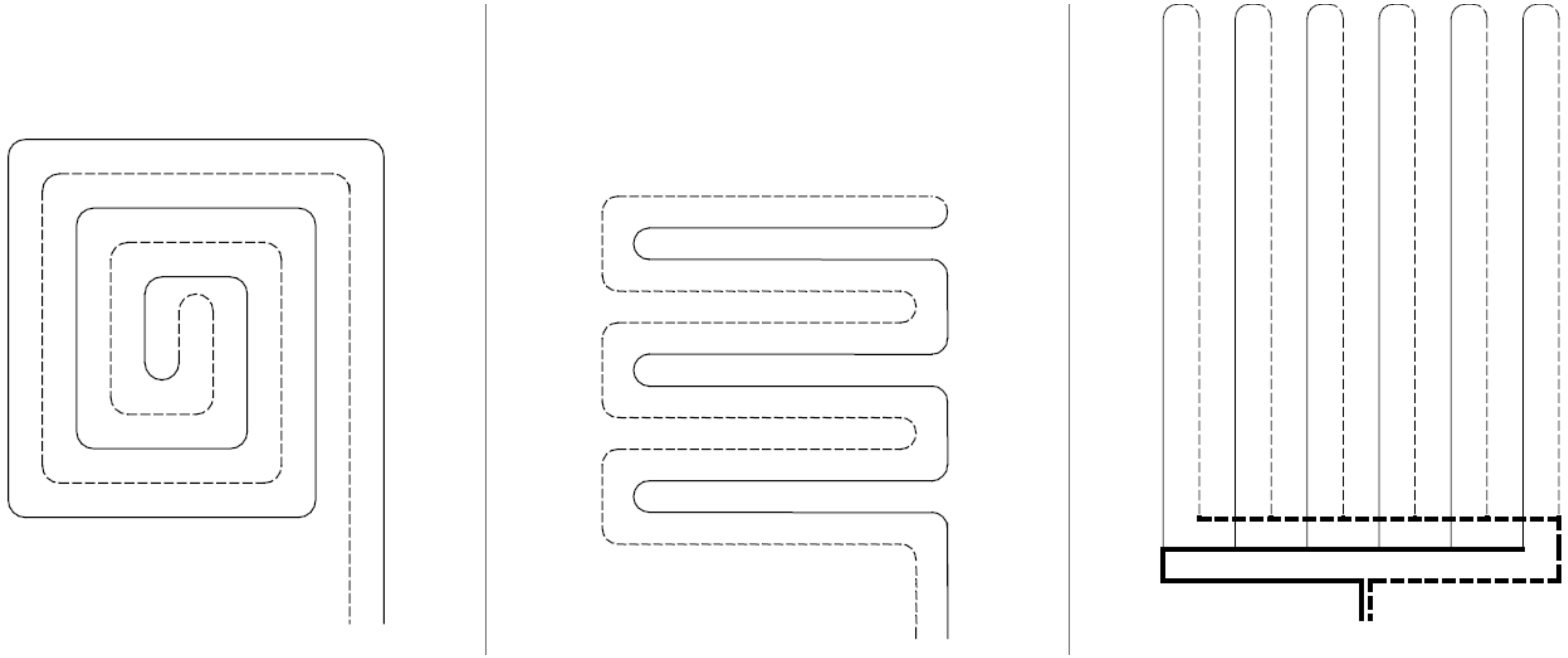
- coherent, low running cost
- stable, relatively high temperature
- high investment costs
- water highly mineralized




a) single well system b) double well system c) single well system witch discharge to sewage

# Heat sources

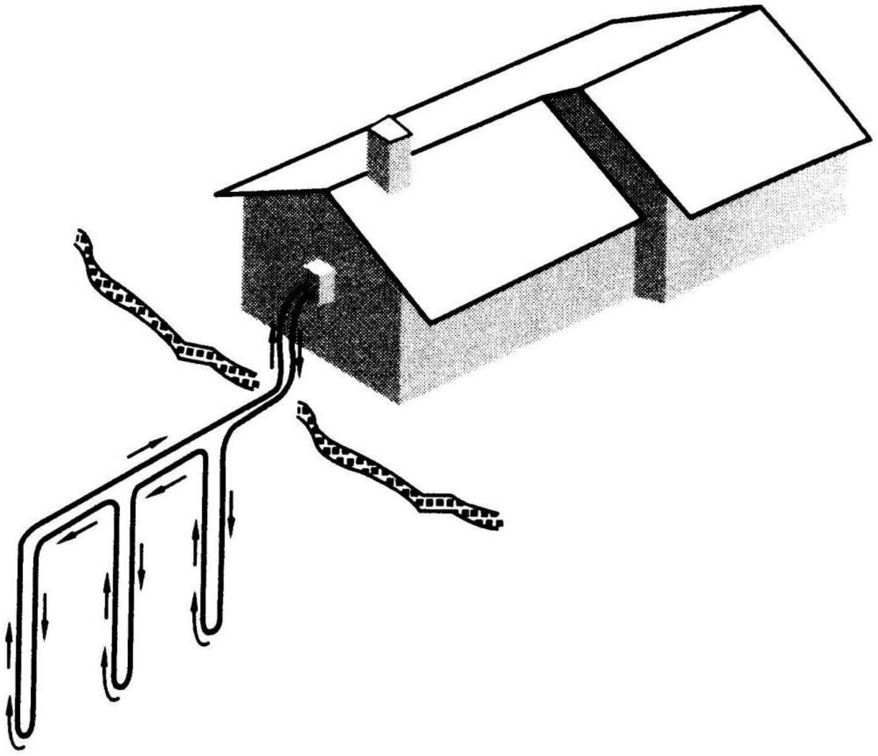
# Heat sources

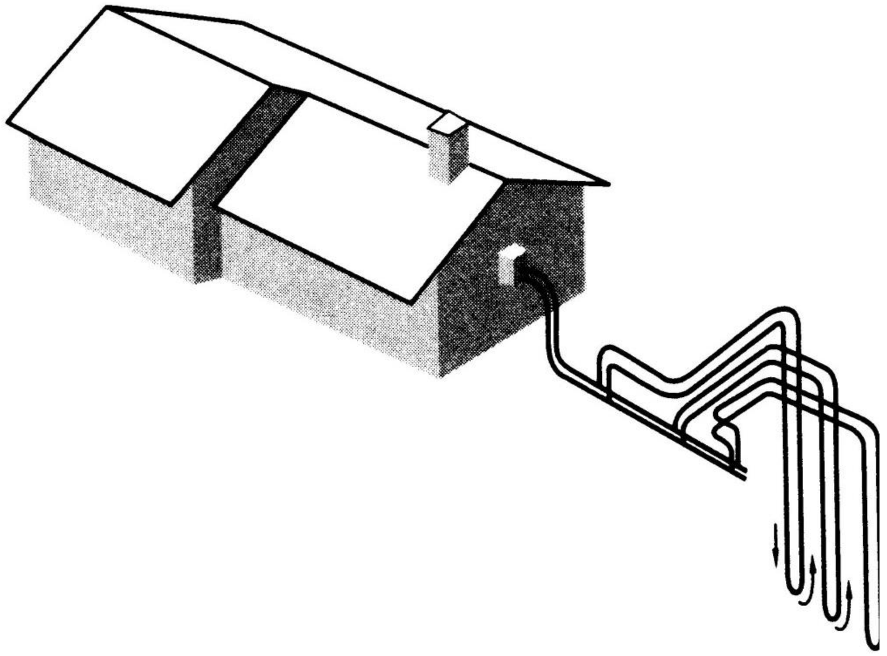


Possible pipe routing arrangements

# Ground source for heat pumps

# Ground source for heat pumps – vertical

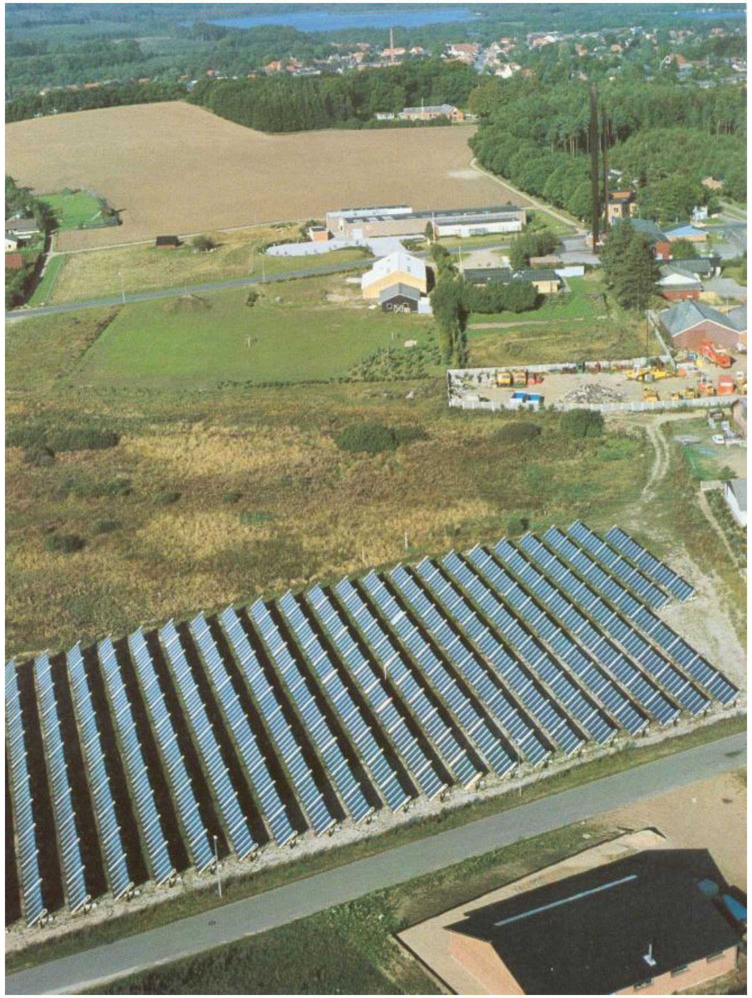


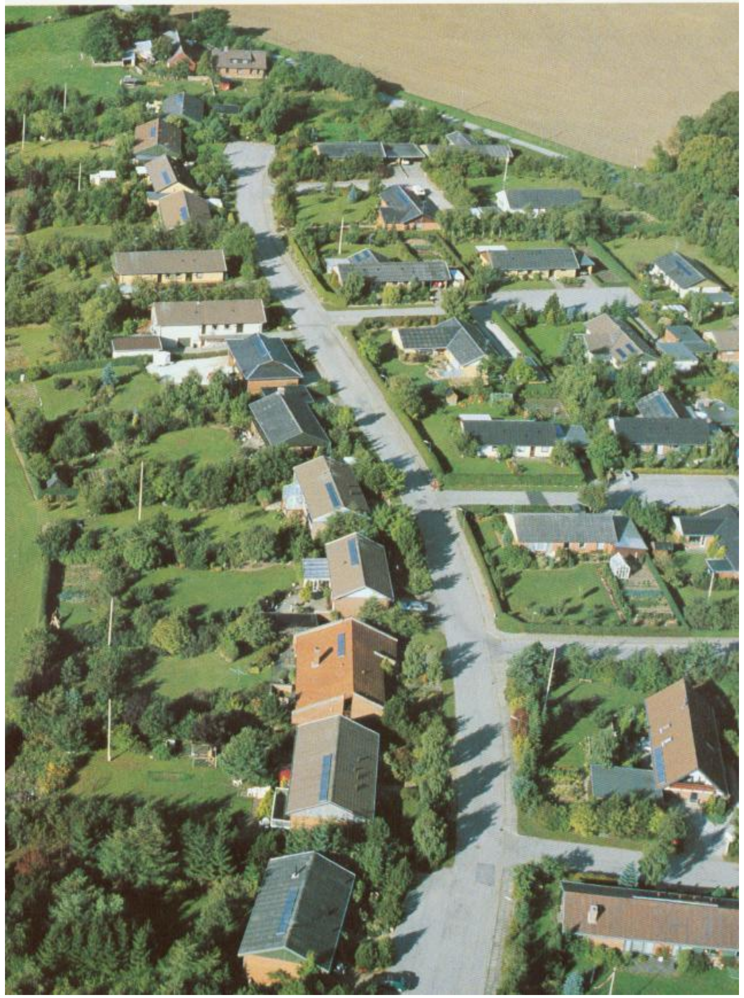


# Geotermal

# Low energy houses

# Solar farms

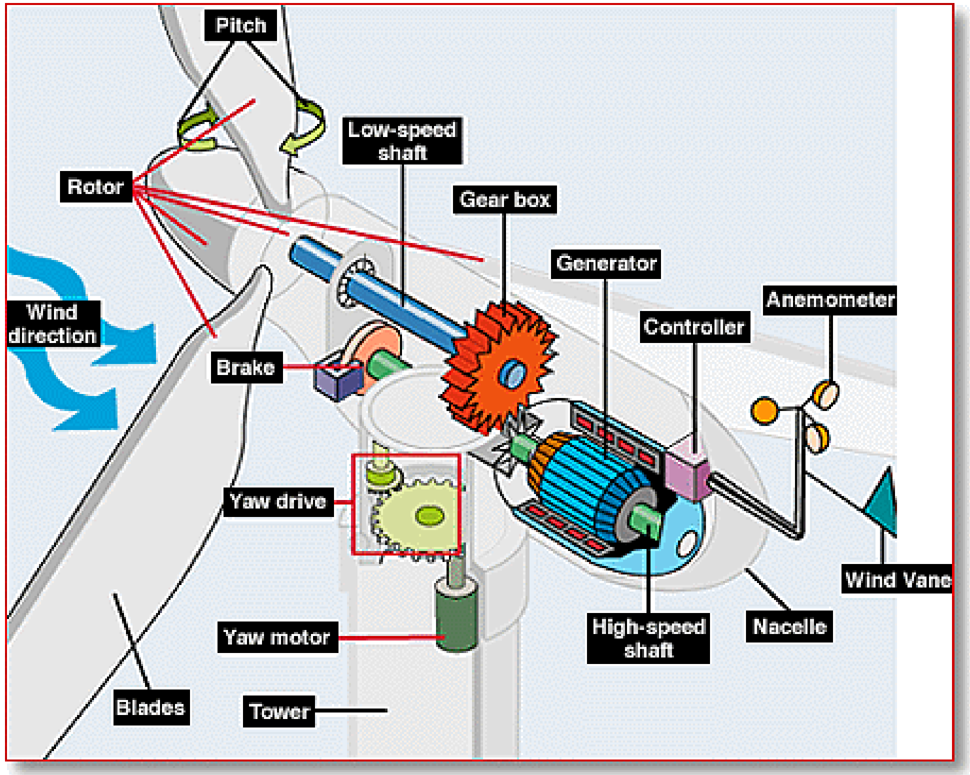




# Solar farms

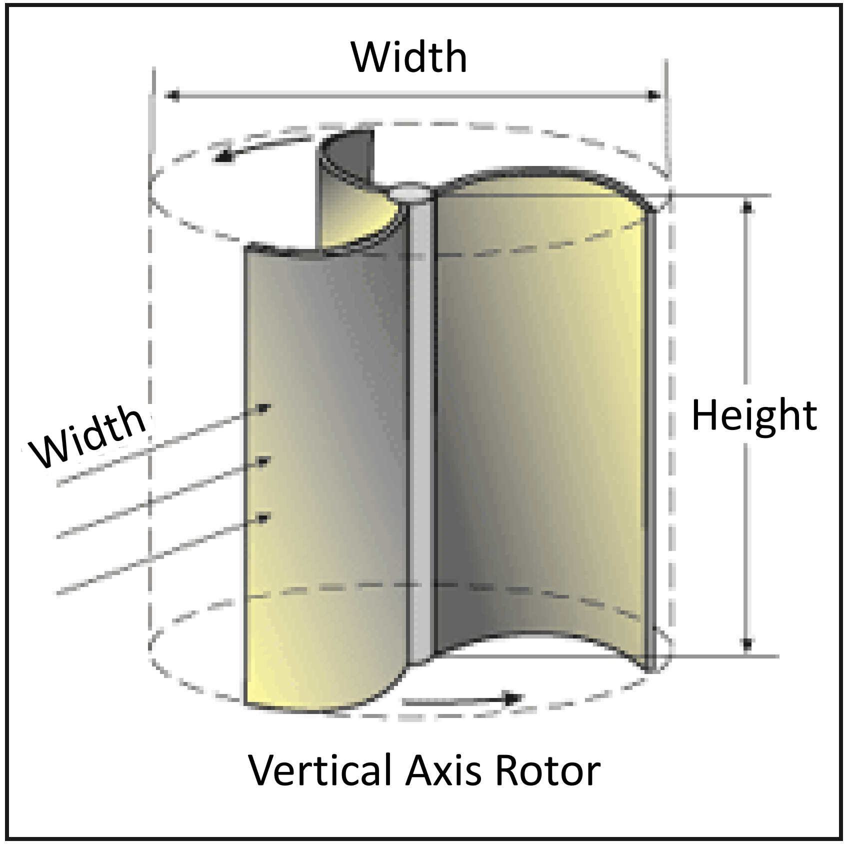
# PV panels

# Wind turbines (*horizontal axis*)



# Wind turbines (*vertical axis*)
## Helix – shaped

Vertical axis devices ares less dangerous to birds but require higher wind speeds



# Wind turbines

Due to the latest regulations alternative energy sources are our future.
The emission of $CO_2$ has to be reduced by eliminating fossil fuel burning.

# Part 6

# *Plumbing installations: introduction*

*Joanna Bąk*

# OUTLINE OF THIS PART:

- Introduction
- Water consumption
- Amount of sewage from households
- Source of water in the households
- Quality of potable water
- Quality of wastewater
- Wastewater disposal solution in the households

This lecture is divided into several parts. As part of the introduction, the basic definitions will be discussed. In the following section, the amount of water using in the household and the quantity of wastewater generated there, will be considered. The next issue discussed will be the sources of water for supplying the population and water quality. The last part of the lecture concerns the quality of domestic sewage and ways of its management.

# Why "plumbing"?

The term "plumbing" is taken from the Latin word "plumbum" which means lead.
Until recently, lead was commonly used for water supply and wastewater removal.

Instead of introduction, the question may be asked: why the word "plumbing"?

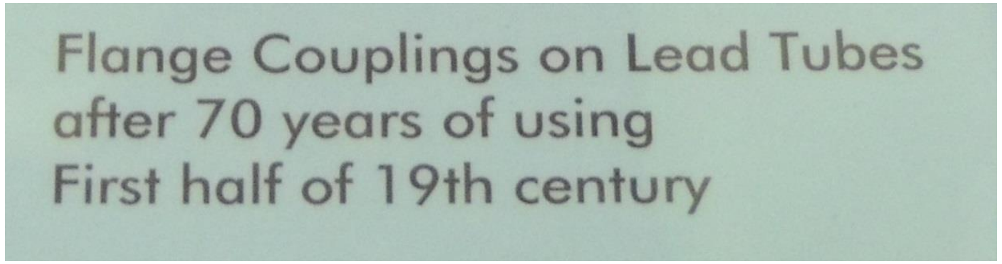



*Photo by J. Bąk*

The picture shows flange couplings on lead tubes after 70 years of using, coming from first half of $19^{th}$ century.
Photography was taken in Prague Waterworks Museum.

# Plumbing

- a system of pipes and fixtures for supplying and carrying off water in a building
- the apparatus (such as pipes and fixtures) concerned in the distribution and use of water in a building

There are many definitions of the word "plumbing". Some give a narrower, others a broader meaning to this expression.

On the next page, several definitions of this word are presented.
These two definitions come from the Merriam Webster dictionary.
They are available at: https://www.merriam-webster.com/dictionary/plumbing

# Plumbing

The following definitions come from other sources:

The system of pipes, tanks, fittings, and other apparatus required for the water supply, heating, and sanitation in a building.

*See: en.oxforddictionaries.com/definition/plumbing*

**Plumbing** – system of pipes and fixtures installed in a building for the distribution and use of potable (drinkable) water and the removal of waterborne wastes. It is usually distinguished from water and sewage systems that serve a group of buildings or a city.

*See: britannica.com/technology/plumbing*

# Water consumption

Nowadays, water is essential for human life, as well as for the normal functioning of the household. It is used for various purposes. The activities to which water is used by man are repeatable and can be collected on a list like the one on the slide. Of course, this list does not exclude other, less typical uses of water.

Purposes for which water is used in the household:

- washing the body
- showering or bathing in the bathtub
- flushing the toilet bowl
- clothes washing
- cleaning
- drinking and cooking
- washing dishes
- other (washing the car, watering the garden, watering the plants)

# Water consumption

- What activity in the household uses the most water?
- What activity has the widest range of water consumption?

Toilet flushing is by far the largest single use of water in the households.
2.5 litres up to 9 litres per one flush.
Typically, flushing cistern capacity is 6 litres.
Old cisterns have a capacity of 9 litres.
When we fill the tub halfway, we usually use 100 liters.

# The structure of water consumption (water intended for living and economic needs – according to Polish technical literature)

'Bath in the bathtub' water use is slightly understated.

| The structure of water consumption | Consumption in [l/capita, day] | | % |
|---|---|---|---|
| | range | average | |
| drinking and cooking | 3÷5 | 4 | 3 |
| washing dishes | 10÷15 | 12 | 10 |
| washing the body | 10÷15 | 12 | 10 |
| bathing (shower/bathtub) | 25÷40 | 33 | 26 |
| flushing the toilet bowl | 30÷45 | 38 | 30 |
| clothes washing | 16÷20 | 18 | 15 |
| cleaning and other needs | 6÷10 | 8 | 6 |
| **together** | 100÷150 | 125 | 100 |

*Source: Chudzicki, Sosnowski 2011*

# Water consumption

- How much water do we use every day?

It depends on the country and place of residence (city/village). 100÷150 l/capita, day

- How much water do we drink a day?

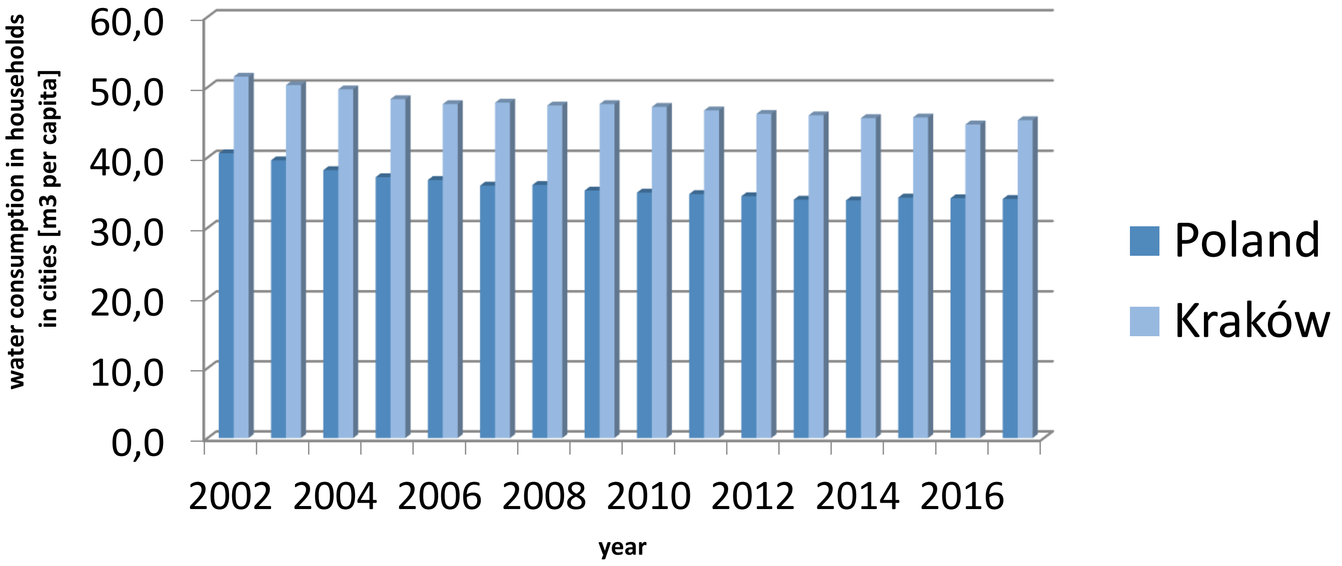
It depends on us and our habits.

- How much water should we drink during the day?

At least 2 liters a day.

# Water consumption Cities in Poland vs. Kraków

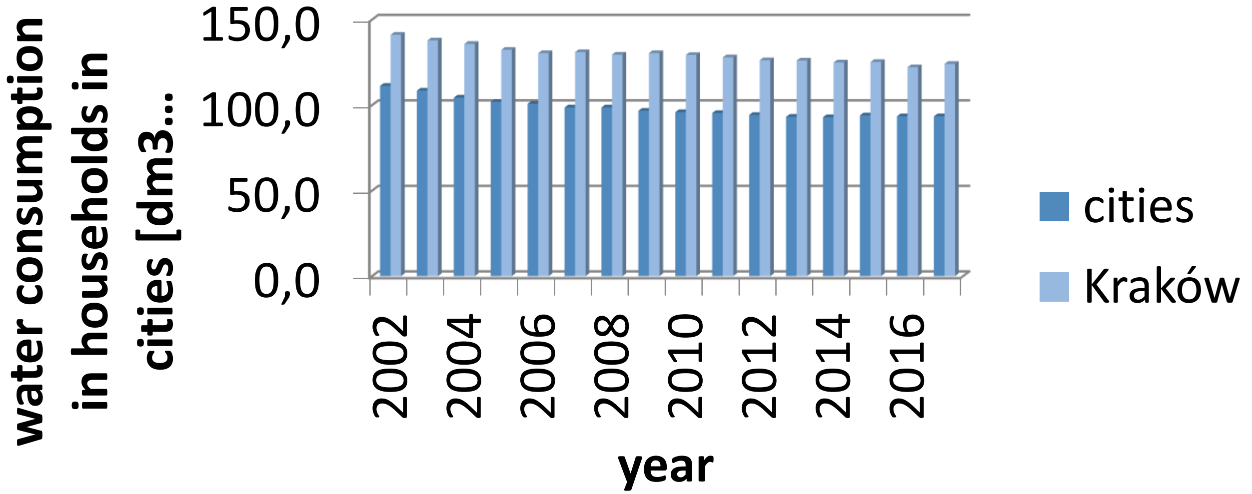
The graph presents a comparison of city water consumption in Krakow versus the general figure for city water consumption in Poland in the years 2002–2017. Data comes from the Local Data Bank of the Central Statistical Office, own elaboration. It can be noticed that water consumption in Kraków is clearly higher than in other Polish cities. The water consumption is given in cubic meters per year per capita. It would be more illustrative to express this value in another unit – in litres per capita per day.




*Source: Local data bank, available at: bdl.stat.gov.pl*

# Water consumption Cities in Poland vs. Kraków

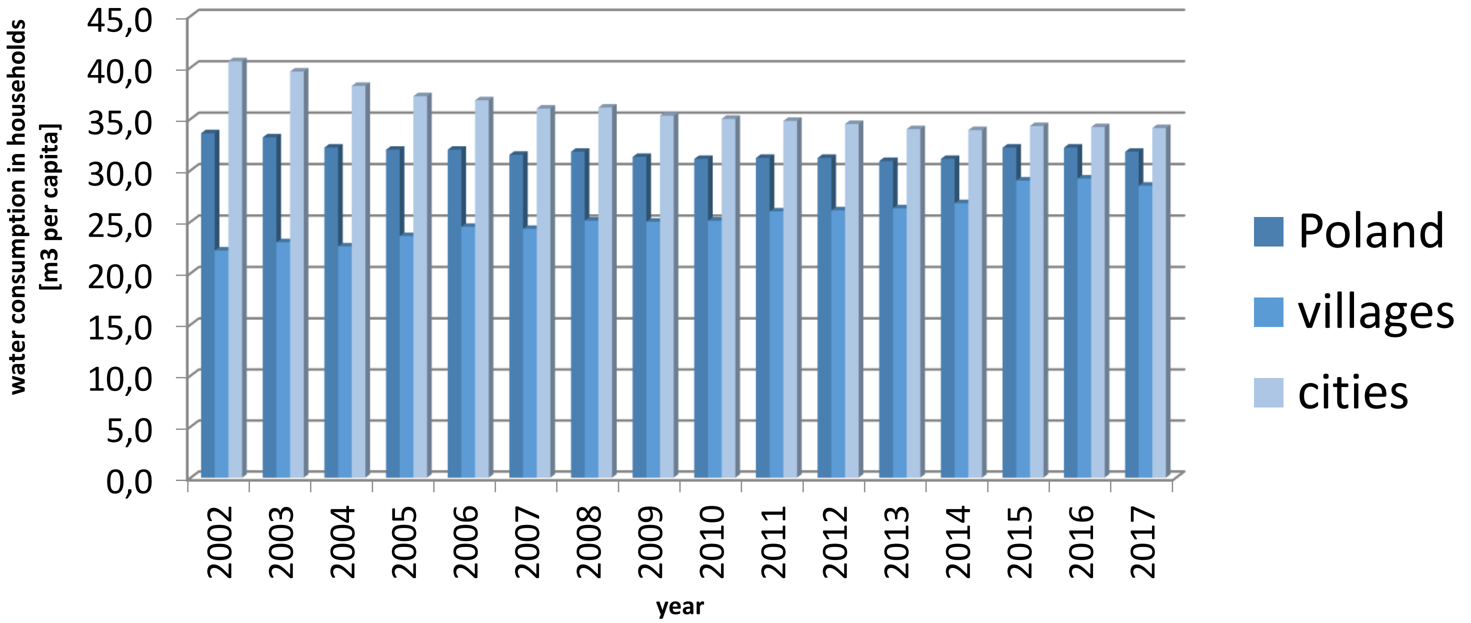
Thios graph shows a comparison of general water consumption in Poland's cities versus that in Kraków (one of the cities in Poland) in the years 2002–2017. Data comes from the Local Data Bank of the Central Statistical Office, own elaboration.  The water consumption is given in litres per year per capita per day. In 2017, water consumption in Kraków amounted to 124.1 litres per capita per day, while in Polish cities in general – 93.4 l/capita, day.




*Source: Local data bank, available at: bdl.stat.gov.pl*

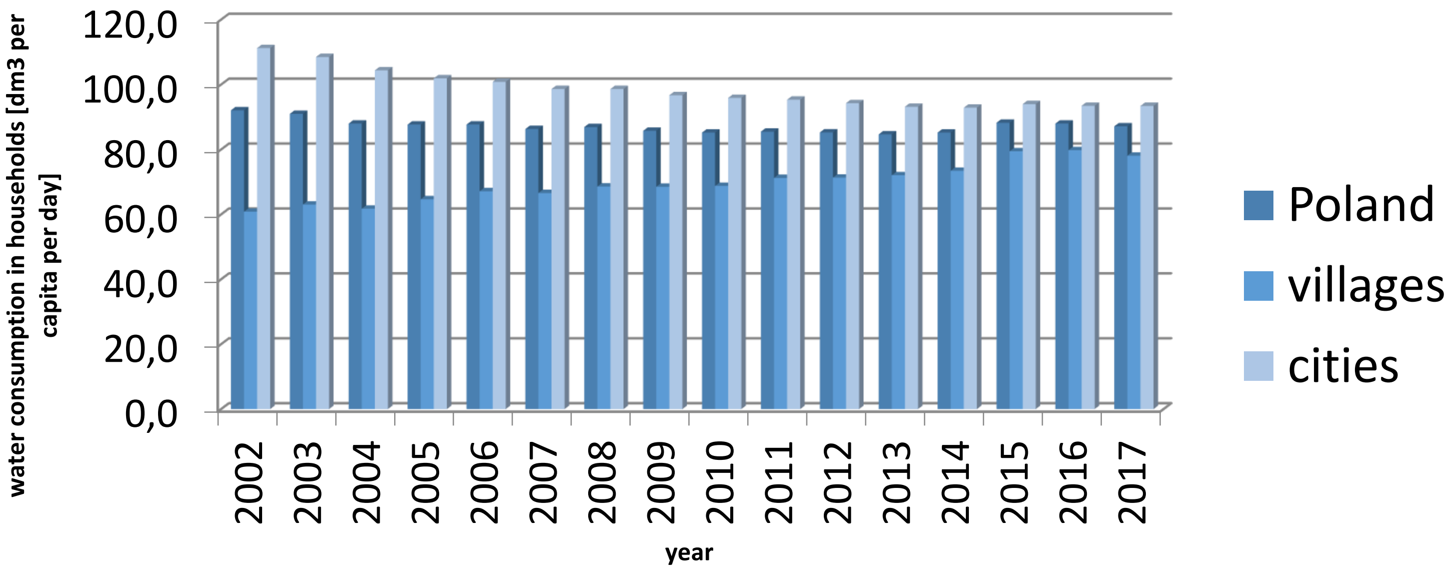
# Water consumption in Poland

Two subsequent graphs show a comparison of consumption in Poland, Polish cities and Polish villages – given in different units (cubic per person per year and litres per capita per day). Data comes from the Local Data Bank of the Central Statistical Office, own elaboration.




*Source: Local data bank, available at: bdl.stat.gov.pl*

# Water consumption in Poland




*Source: Local data bank, available at: bdl.stat.gov.pl*

# Wastewater production

- How much wastewater do we produce per day in the household?

The amount of wastewater is equal to 95% of water consumption.

95% from (100÷150 l/day) = 95÷142.5 l/day

- How many times do you use the toilet every day?

On average, a person urinates 4 to 6 times a day.

The amount of wastewater is equal to 95% of all water consumption (for housing and general urban purposes).

Usually a man/woman uses the toilet 4 to 6 times a day just to urinate.

# Wastewater production

- How much urine does a person usually give a day?

1,500 ml of urine (350 ÷ 400 ml every 3 hours)

- ✓ more urine can be given after a hot or cold bath
- ✓ more urine can be given in the case of a large amount of liquid consumed

Physiologically, a man/woman should give urine about every 3 hours in the amount of 350÷400 ml – assuming that he/she drinks the correct amount of fluids (water, beer, etc.) per day.

# Source of water for buildings

It depends on the location of the buildings, climate, purpose of use and water availability.
We distinguish the following sources of water for buildings:

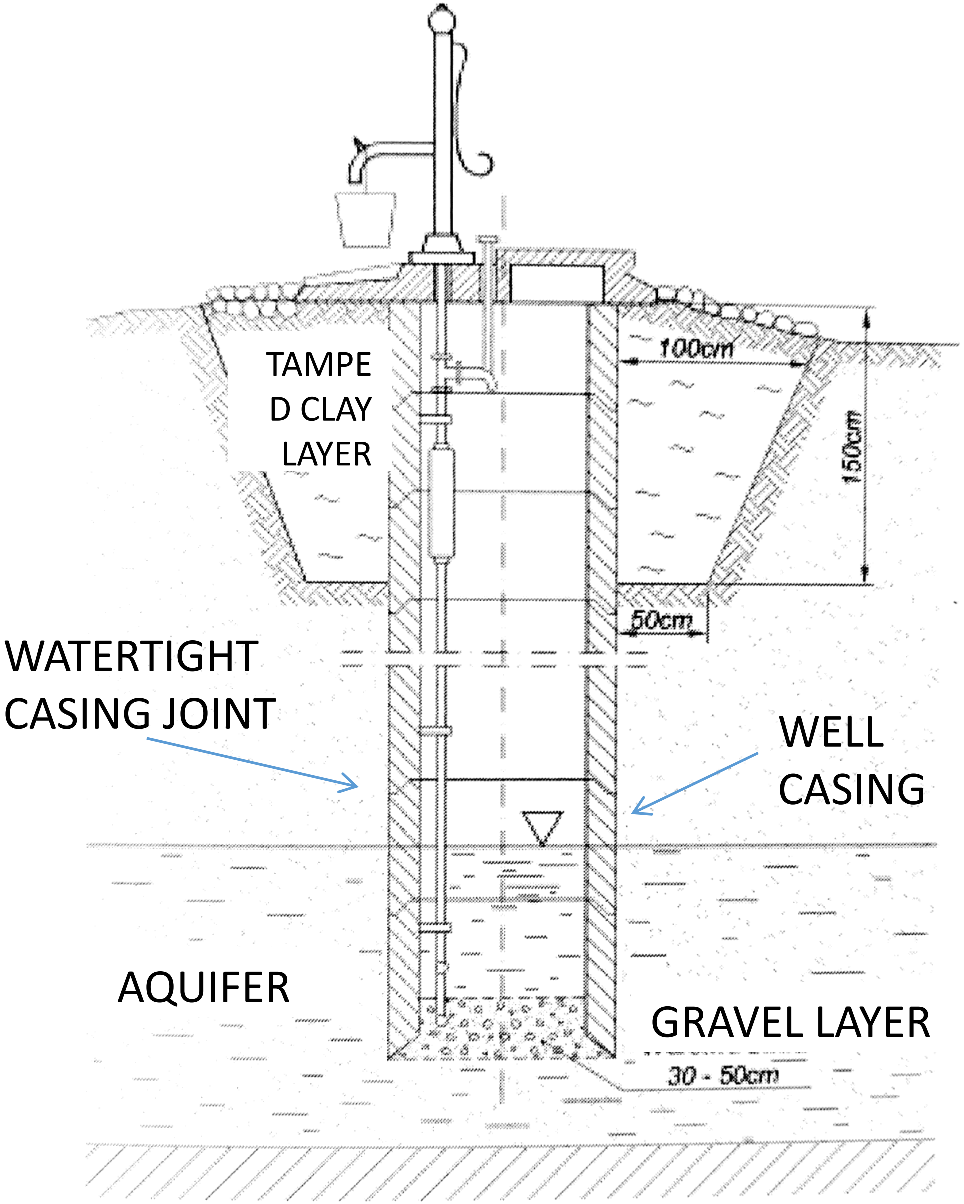
1. Private intakes
   - dug wells/bored wells
   - drilled wells
   - driven well
   - rainwater
2. Public water supply systems

# Dug well

The drawing shows the elements of a dug well. This dug well is supplied by the bottom.

The word "watertight" means closely sealed, fastened, or fitted so that no water enters or passes through.

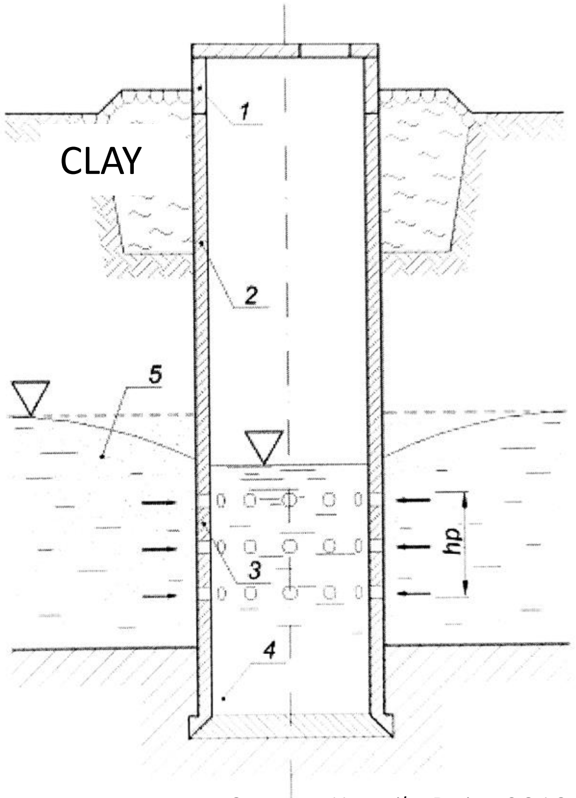
For shallow wells, jet pumps are usually used. This type of pump is mounted above ground and use suction to abstract water from a dug well.




*Source: Knapik, Bajer 2010*

# Dug well

The drawing shows an another type of dug well – with side water inflow.




*Source: Knapik, Bajer 2010*

hp – the height of perforation of the well cladding pipe

# Gravel vs. Sand

In the drawing of the dug well, among others, the aquifer could be sand and gravel.

*Source: centrumkostki.com.pl*

*Photo by J. Bąk*

# Dug well

- a shallow large diameter man-made pit or hole, from which groundwater can be abstracted
- constructed pit or hole in soft geological formations such as alluvium adjacent to rivers
- is normally dug by hand or using an excavator
- generally has a diameter larger than 0.5 m

A dug well is a shallow large diameter man-made pit or hole from which groundwater can be abstracted.

It is a constructed pit or hole in soft geological formations such as alluvium adjacent to rivers. This type of well is normally dug by hand or by using an excavator. Generally, a dug well has a diameter larger than 0.5 m.

Dug wells provide access to the shallow sub-surface and can be used for abstracting and monitoring groundwater. They are inexpensive to construct and provide easy access to shallow groundwater. Because of these advantages, they are widely used around the world.

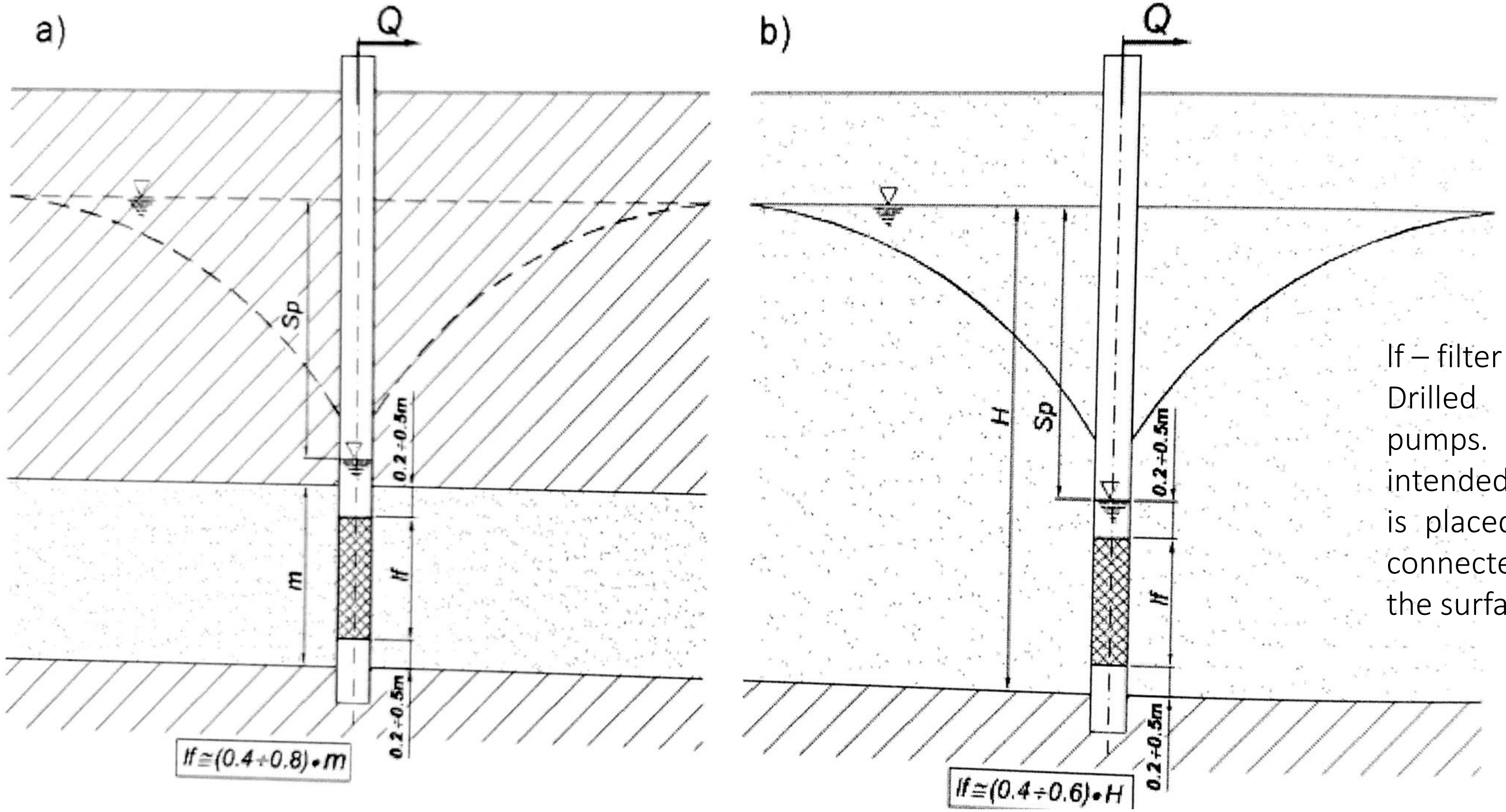
*According to "The groundwater dictionary"*

# Dug well

- provides access to the shallow sub-surface and can be used for abstracting and monitoring groundwater
- inexpensive to construct and provides easy access to shallow groundwater
- widely used around the world

# Drilled well

The drawing shows drilled wells.




lf – filter length

Drilled wells use submersible pumps. This type of pump is intended for deep wells. The pump is placed in the well casing, but connected to a power source in the surface.

*Source: Knapik, Bajer 2010*

# Drilled well

- constructed by percussion or rotary-drilling machines
- can be 1,000 m deep
- require the installation of casing
- have a lower risk of contamination because of the depth and use of continuous casing

These type of well are constructed by percussion or rotary-drilling machines. Drilled wells can be 1000 metres deep, but most commonly they are not more than 30 metres deep. They require the installation of well casing. In this type of wells, risk of contamination is lower because of their depth and continuous casing.

Another type of wells are driven wells. They are constructed by driving pipe into the ground. They are shallow and can be easily contaminated. They have continuous casing.

# Rainwater harvesting

THAILAND

- storing rainwater from rooftop run-off in jars
- various capacities, from 100 to 3,000 litres
- equipped with lid, faucet, and drain

Another way to get water is by harvesting of rainwater. The picture presents the example of a rainwater jar as used in Thailand.

In Thailand, residents use jar-stored rainwater from rooftop run-off. It is an appropriate and cheap means of obtaining high quality drinking water in this country. Before the introduction of these jars, many communities had no means of protecting drinking water from waste and mosquito infestation.

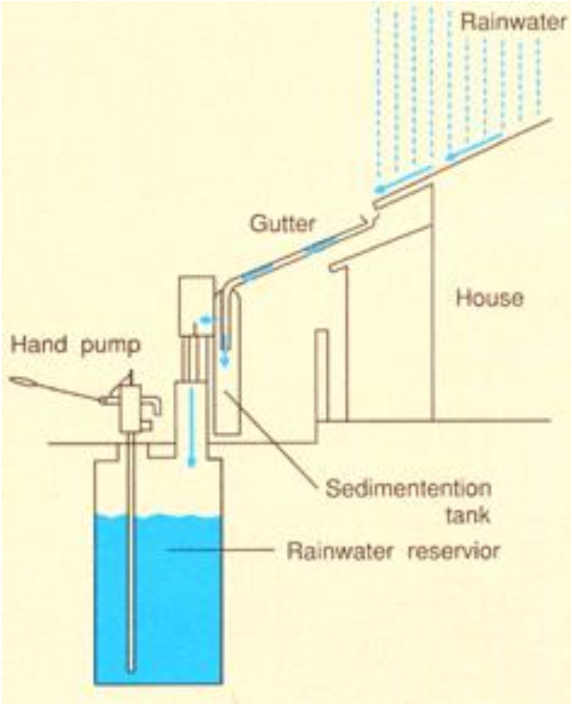
The jars have different capacities, from 100 up to 3,000 litres, but the most common used is in the 2,000 litres size. This volume of rainwater is sufficient for a six-person household during the dry season that lasts up to six months.

*Source: unep.or.jp/ietc/Publications/ Urban/UrbanEnv-2/9.asp*

# Rainwater harvesting

Another example of using collected rainwater is the very simple and unique facility called a "Rojison", the shown example being located in Tokyo, Japan. It consists of gutter, sedimentation tank, rainwater reservoir and hand pump. It has been set up by local residents in the Mukojima district of Tokyo to utilise rainwater collected from the roofs of private houses. Rainwater is used for garden watering, fire-fighting and as drinking water in emergencies.

The picture is of a "Rojison" – rainwater utilisation facility at the community level in Tokyo, Japan.




*Source: unep.or.jp/ietc/Publications/Urban/UrbanEnv-2/9.asp*

# Rainwater harvesting

In addition to various individual solutions for the use of rainwater used in the world, there are standard solutions for domestic and industrial purposes.

The picture shows a system for using rainwater in a single-family building. The building has a dual installation. Water from the rainwater tank is supplied to the washing machine, the toilet and to a valve outside the building (for watering the garden).

*Source: mpi.com.pl/bazy_wiedzy/woda-deszczowa-systemy-pompowe-i-centrale-deszczowe/*

# Rainwater harvesting

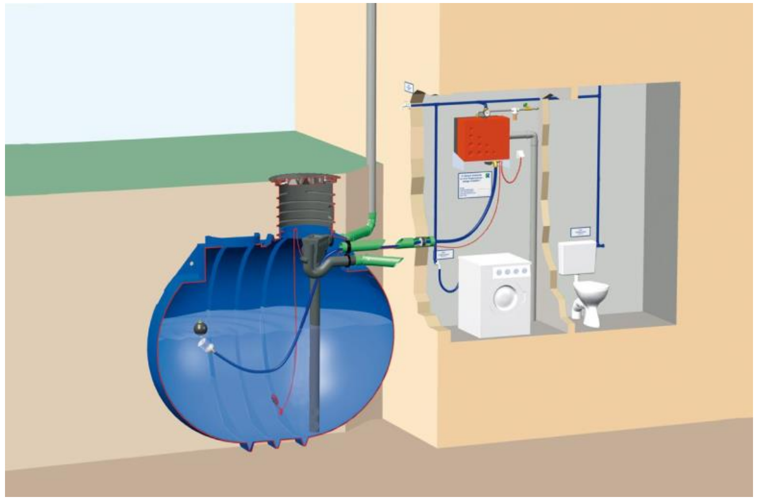
This picture shows another example of a rainwater system in a single-family building.

*Source: rainwaterharvestingservice.com/rainwater-system.html*

# Rainwater harvesting two ways of supplying rainwater to household

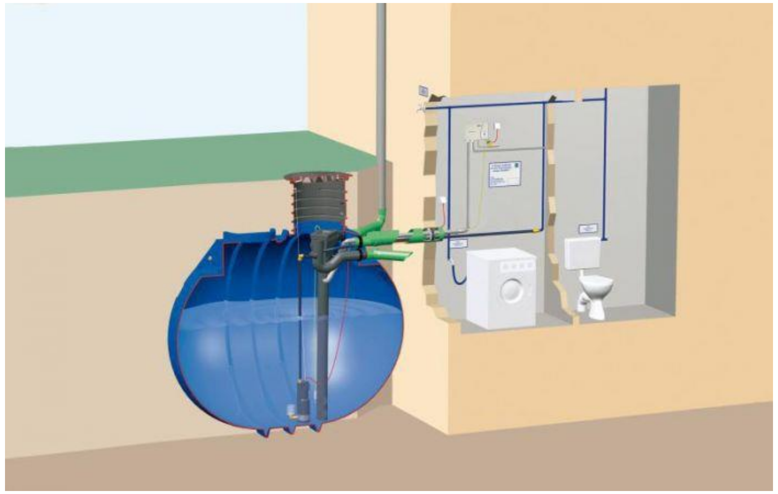
The drawings show two ways of delivering rainwater to a single-family building. The first way is the use of the rainwater unit. The second method is the use of a submersible pressure pump with a device for automatically filling the underground reservoir with tap water.

Rainwater units



*Source: zagospodarowanie-wody-deszczowej.pl/zagospodarowanie-wody-deszczowej-zbiorniki-na-wode-deszczowa-lub-scieki-dekoracyjne-zbiorniki-na-wode-deszczowa-zbiorniki-na-wode-pitna-centrale-pompy-zestawy-do-wody-deszczowej-zbieracze-i-filtry-na-rury-spustowe-elastyczne-zbiorniki-na-wode/zestaw-z-aqu_p_1508.html*

A submersible pressure pump with a system for emergency replenishment of the tank



*Source: baustoffshop.de/rewatec-blueline-ii-hausanlage-diver-10-000-liter.html*

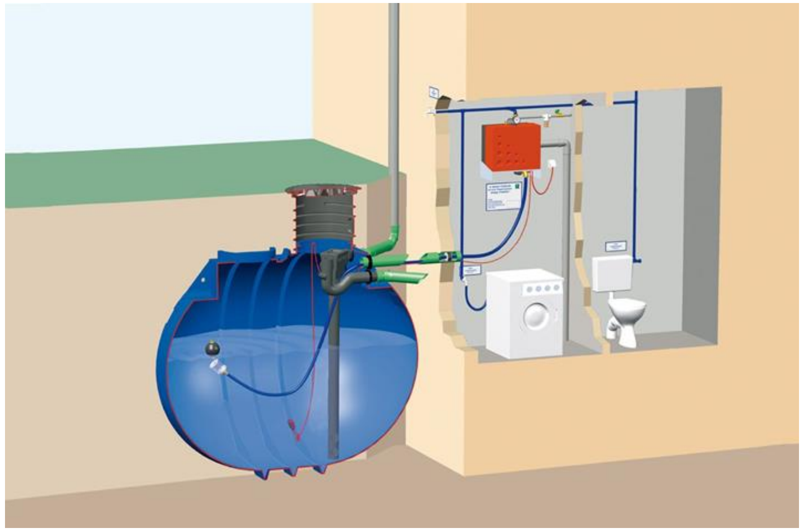
# Rainwater harvesting

In single-family residential buildings, harvested rainwater can be accessed in two ways:

- by means of a **rainwater unit** installed in the building (boiler room, garage, technical room)
- by means of a **pressure pump immersed** in the tank and automatic filling device for the underground tank (with tap water)

# Rainwater harvesting: rainwater units

The picture presents a system with a rainwater unit. The insert shows the rainwater unit. The unit consists of a console, a self-priming centrifugal pump, an intermediate tank with an air gap. In the absence of rainwater in the tank, the control panel allows the automatic use of pottable water: it is enabled by a three-way valve controlled by a float switch located in the rainwater tank.



*Source: zagospodarowanie-wody-deszczowej.pl/zagospodarowanie-wody-deszczowej-zbiorniki-na-wode-deszczowa-lub-scieki-dekoracyjne-zbiorniki-na-wode-deszczowa-zbiorniki-na-wode-pitna-centrale-pompy-zestawy-do-wody-deszczowej-zbieracze-i-filtry-na-rury-spustowe-elastyczne-zbiorniki-na-wode/zestaw-z-aqu_p_1508.html*

*Source: mpi.com.pl/bazy_wiedzy/woda-deszczowa-systemy-pompowe-i-centrale-deszczowe/*

# Rainwater harvesting: rainwater units

The picture displays another example of a system with a rainwater unit.

*Source: mpi.com.pl/wp-content/uploads/2017/11/Grafik-Hausanlage-NEO-McRain-2017.jpg*

# Rainwater harvesting: rainwater units

The complete rainwater unit consists of:

- console,
- multi-stage, self-priming centrifugal pump,
- intermediate tank with an air gap.

Advantage: location of the pump and electrical and mechanical accessories in the building

- it facilitates inspections and servicing of equipment

When the **distance between the underground tank and the location of the rainwater unit is large**, another solution is suggested.

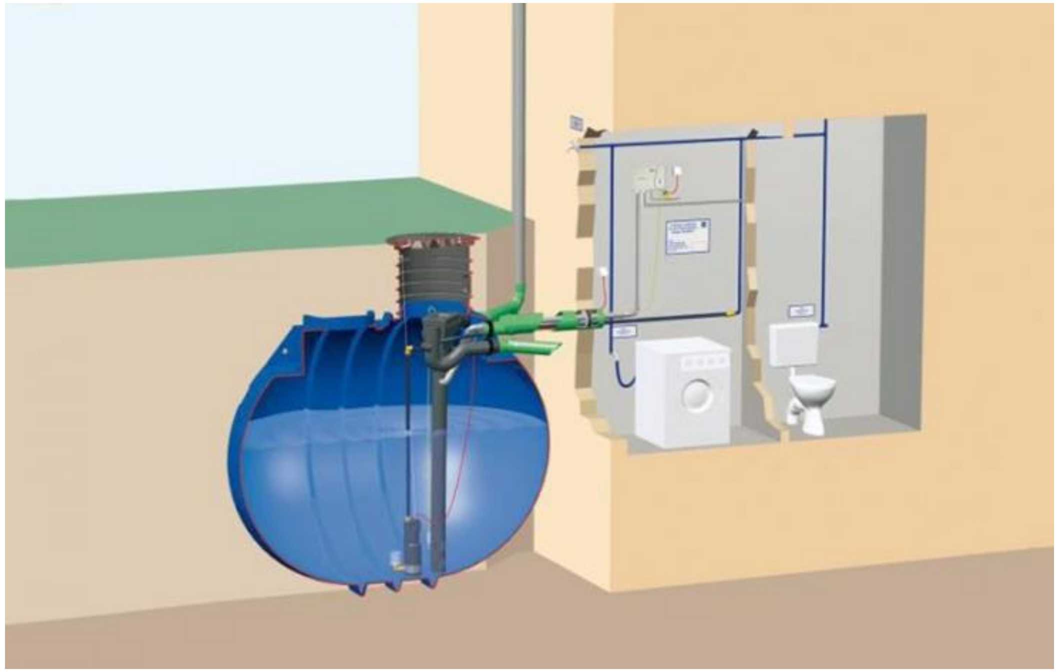
The suction height of the pump is limited!

The advantage of this solution is the location of the pump and electrical and mechanical accessories in the building, which greatly facilitates possible inspections and servicing of equipment.

It is extremely important to remember that the suction height of the pump is limited. A system with rainwater unit (including the pump) is not a suitable solution when the distance between the underground tank and the location of the rainwater unit is large. The same situation is when we have a deeply seated rainwater tank.

# Rainwater harvesting: another solution

In the case of a distant or deeply seated rainwater tank, a solution with a submersible pressure pump and automatic topping with tap water is used.
The filling set consists of an solenoid valve connected to a level sensor or a float switch off.



*Source: baustoffshop.de/rewatec-blueline-ii-hausanlage-diver-10-000-liter.html*

# Use of water and rainwater at the national stadium in Warsaw

At the National Stadium in Warsaw, rainwater is collected from its roof and is used, among others, to flush toilets.


*Photo by J. Bąk*

# Drinking water quality

- Microbial aspects (bacterial pathogens, viral pathogens, protozoan pathogens, helminth pathogens, indicator organisms – Escherichia coli, Clostridium perfrigens)
- Chemical aspects
- Radiological aspects
- Acceptability aspects (taste, odour, appearance)

*Source: Guidelines for drinking water quality, WHO 2011*

# Types of wastewater

Types of wastewater, or sewage:

- domestic sewage
- industrial sewage
- storm sewage
- raw sewage, untreated sewage
- treated sewage

# Types of wastewater

**Domestic sewage** carries used water from houses and apartments; it is also called **sanitary sewage**. **Industrial** sewage is used water from manufacturing or chemical processes.

**Storm sewage**, or **storm water**, is runoff from precipitation that is collected in a system of pipes or open channels.

# Domestic wastewater quality

The table presents the scale of pollution in domestic and economic wastewater determined on the basis of American studies.

| Pollution indicators | Concentration of pollutants (low – high) | Unit |
|---|---|---|
| five days biochemical oxygen demand (BOD) | 110–400 | $g/m^3$ |
| chemical oxygen demand (COD) | 250–1,000 | $g/m^3$ |
| total nitrogen | 20–85 | $gN/m^3$ |
| organic nitrogen | 8–35 | $gNorg/m^3$ |
| ammonium nitrogen | 12–50 | $gN\text{-}NH4/m^3$ |
| total phosphorus | 4–15 | $gP/m^3$ |
| organic phosphorus | 1–5 | $gPorg/m^3$ |
| total suspension | 100–350 | $g/m^3$ |

*Source: Heidrich 1999*

# Domestic wastewater quality

The table presents the values of pollution indicators of household sewage(chemical parameters).

Concentration of pollutants assuming water consumption at the level of 150–170 $dm^3$/capita, day

| Pollution indicators | Concentration of pollutants | Unit |
|---|---|---|
| five days biochemical oxygen demand (BOD) | 350–400 | $gO_2/m^3$ |
| chemical oxygen demand (COD) | 680–730 | $gO_2/m^3$ |
| total nitrogen | 35–100 | $gN/m^3$ |
| ammonium nitrogen | 6–18 | gN-NH4/$m^3$ |
| total phosphorus | 18–29 | $gP/m^3$ |
| total suspension | 200–290 | $g/m^3$ |

*Source: Osmulska-Mróz 1992*

# Wastewater disposal solution

- Public sewerage system
  - ✓ Combined sewerage system
  - ✓ Separate sewerage system
- Local sewage disposal and treatment system

It is used when public sewerage system is not available.

# Local sewage disposal and treatment system

The sewage storage and disposal method depends on:

- groundwater level
- soil permeability
- depth to bedrock
- holding tanks
- septic tanks and soil adsorption systems

# Part 7

## *Plumbing fixtures and appliances*

*Joanna Bąk*

# OUTLINE OF THIS PART:

- Introduction
- Water service line
- Materials
- Water meters
- Water pressure
- Multi storey buildings
- Hot water installation
- Calculating methods

This part is divided into several parts. As part of the introduction, the water installations in buildings will be listed. The next part concerns definition and characteristics of water service lines. In the following section, materials that are used in construction of water plumbing installations will be considered. The water meters used will also be discussed. Water pressure will be also talked through.

The next issues discussed will be installations in multi storey buildings and hot water installations. The last part of the lecture concerns calculating methods.

# Why "plumbing"? Why "fixture"?

The term "plumbing" is derived from the Latin lamguage. The word "plumbum" means lead.
The term "fixture" means equipment, fittings.


*Photo by J. Bąk*

The picture shows damaged lead tubes – the 1930's. Photography was taken in Prague Waterworks Museum.

# Plumbing fixtures and appliances

There are many different plumbing fixtures and appliances. They differ from each other due to their function. In addition, each type of plumbing fixture usually has several varieties and models. The same concerns appliances. A very interesting group among plumbing fixtures are the integrated facilities.

Plumbing fixtures include:

- lavatories
- sinks
- bathtubs
- showers as one-piece assemblies and shower bases
- water closets
- bidets
- urinals
- drinking fountains

and also

- laundry trays
- service sinks
- mop basins.

Between appliances include:

- food waste disposers
- dishwashers
- washing machines
- water coolers
- water softeners
- water filters
- water heaters
- ‘washing toilets’.

# Plumbing fixtures sanitary facilities

A plumbing fixture (or sanitary facility) is any device (or receptacle/reservoir) that is connected (permanently or temporarily) with the water distribution system, requires the supply of drinking water (pottable water) and discharges sewage (directly or indirectly) into a sanitary drainage system.
The exception are the waterless urinals, which do not require connection to tap water.
Another name used for "plumbing fixtures" is "sanitary facilities".

# Plumbing fixtures

A plumbing fixture is the first element of a sanitary drainage system. It is a place where household wastewater is formed, collected or flows.

It is at the end of the water supply system and the start of the sewage system.

Among the plumbing fixtures are facilities well known to everyone, as well as new innovative solutions which are just gaining popularity.

# Plumbing fixtures

Common fixtures include lavatories, water closets, showers, bathtubs, bidets and sinks.
Among the innovative solutions, it is worth mentioning the toilet bowl integrated with the bidet, or the urinal integrated with the basin. A solution such as a bidetta is not yet widespread around the world.

# Plumbing appliances

An appliance is a plumbing fixture that carries out a special function, is controlled and/or energized by engines, heating elements, or pressure – or temperature-sensing elements.

Common appliances include washing machines, dishwashers, water heaters and food waste disposers. A modern solution that is gaining increasing popularity is the washing toilet.

# Fixture trim

A fixture trim is the water supply and drainage fittings installed on a fixture or appliance to control:

- flow of water into a fixture
- flow of wastewater from the fixture to a sanitary drainage system.

Common fixture trims include a faucet and the lavatory drain fitting (or kitchen sink drain fitting) through which used water drains from the lavatory (or sink).

# Requirements for plumbing fixtures

There are many regulations and guidelines for plumbing fixtures.
These requirements cover such items as:

- construction material
- connections
- installation
- overflows
- prevention of backflow
- inlet/outlet size
- minimum number of each type of plumbing fixture that must be installed in buildings of various occupancies.

# Minimum plumbing fixtures for various occupancies

The table lists the minimum number of such plumbing fixtures as water closet, urinal and lavatory for offices and public buildings. The number of washbasins is identical for both women and men. The number of water closet for female toilets is definitely higher than for men's toilets. For example, for 100 men, 1 water closet and 1 urinal (2 plumbing fixtures) are required, while for females, 4 water closets are mandatory.

| Type of building and occupancy | Office or public building | | Office or public building – for employee use | |
|---|---|---|---|---|
| Type of plumbing fixture | male | female | male | female |
| water closet | 1 for 1–100 | 3 for 1–50 | 1 for 1–15 | 1 for 1–15 |
| | 2 for 101–200 | 4 for 51–100 | 2 for 16–35 | 3 for 16–35 |
| urinal | 1 for 1–100 | – | 0 for 1–9 | – |
| | 2 for 101–200 | – | 1 for 10–50 | – |
| lavatory | 1 for 1–200 | 1 for 1–200 | 1 for 40 | 1 for 40 |
| | 2 for 201–400 | 2 for 201–400 | | |

*Source: Gladfelter, Olsen 2001*

# Requirements for plumbing fixtures

- Plumbing installations should be designed, constructed and operated in accordance with applicable regulations and guidelines
- Following regulations and guidelines prevents illness and death from unsanitary and unsafe conditions in the supply of water and removal of sewage (i.e. burns and scaldings)

It is extremely important that the installations are designed and built and operated in accordance with applicable regulations and guidelines.

These requirements prevent illness and death from unsanitary and unsafe conditions in the supply of water in buildings and removal of sewage in pipe.

# Health requirements for plumbing fixtures

- should be provided with water in sufficient volume and at pressure adequate to enable them to function properly
- should be located in ventilated enclosures and should be readily accessible to users

Sanitary facilities should be provided with water in sufficient volume and at pressure adequate to enable them to function properly.
They should be located in ventilated enclosures and should be readily accessible to users.

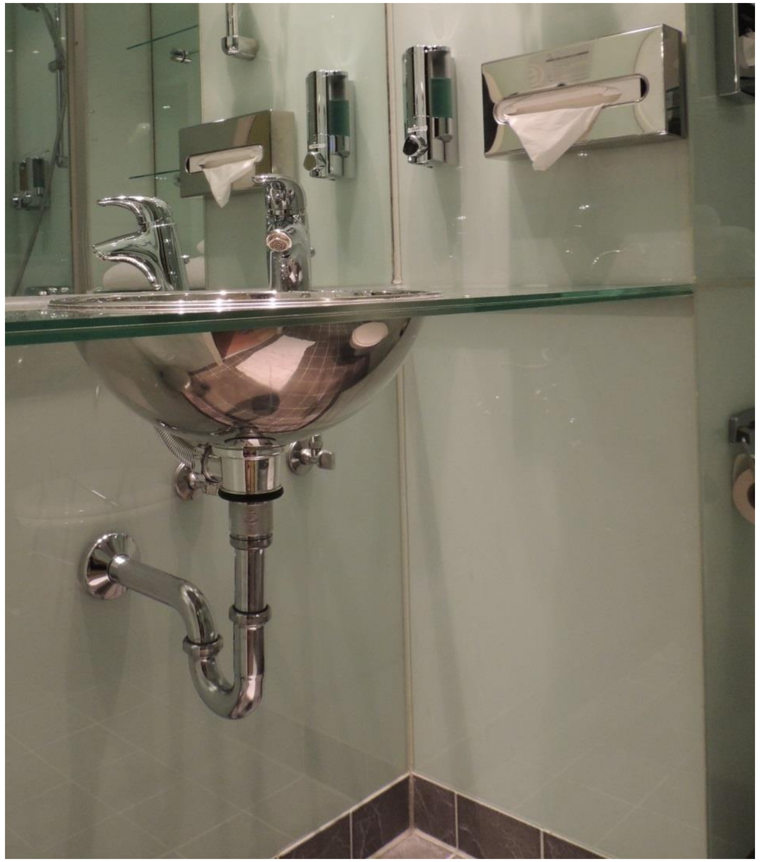
# Health requirements for plumbing fixtures

Every fixture that is directly connected to the sanitary drainage system should be equipped with a liquid – seal trap.

Its construction prevents passage of air/gas through a pipe and at the same time permits for flow of wastewater through a pipe to the sanitary drainage system.

# P-traps

The pictures present the example of a P-trap for lavatory. These types of traps are typically installed for wall-hung and floor-set fixtures that do not have integral traps.



# Requirements regarding plumbing fixtures

For plumbing fixture requiring both hot and cold water, the pressure at the outlets for both supplies should be nearly equal. This is achieved by laying-out the distribution system properly.
Doing so prevents the supply at a higher pressure from forcing its way into the lower – pressure supply when the valves are opened to mix hot and cold water. This is important where mixing valves may be installed.
For fixture requiring hot water that are over 760 cm (25 ft) away from the source of hot water,
a temperature maintenance system should be provided by designers (in large hot water distribution systems).
A reduced temperature of hot water can cause excessive growth of Legionella bacteria. This is especially important when delivering hot water to the shower.

# Requirements regarding plumbing fixtures

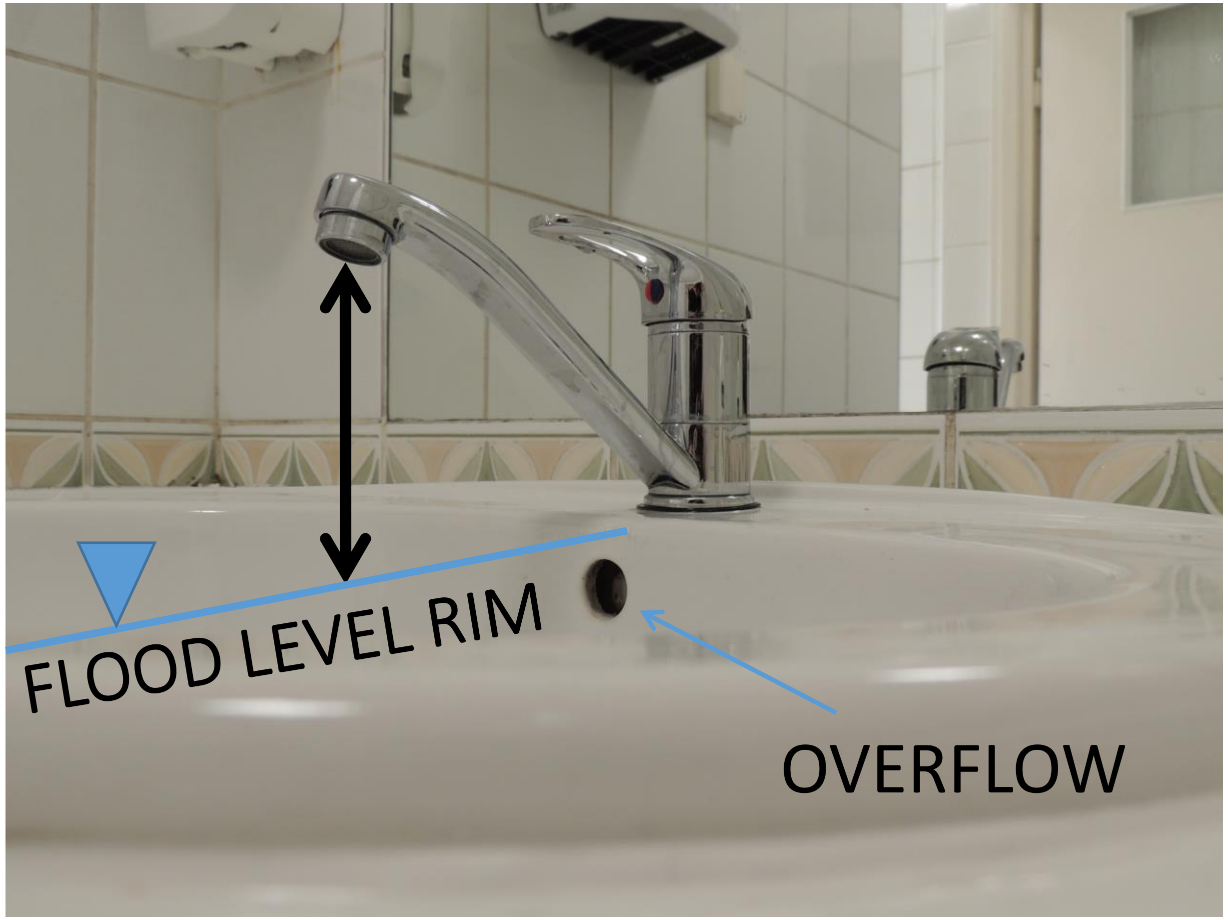
Plumbing fixtures should be protected to prevent contamination of food, water, sterile goods or similar material by the backflow of wastewater.

PREVENTION OF BACKFLOW

The minimum air gap (required by regulations) should be maintained at all times prevent of backflow of water. It is the distance between the fixture water supply outlet and the flood – level rim of receptacle.

# Air gaps

The picture shows an air gap for a washbasin. It is the distance between the outlet of the faucet and flood level rim.



# Requirements for plumbing fixtures


- functional
- durable
- well-made
- attractively designed
- accessible in different colours
- available in a variety of styles
- useful
- comfortable shape
- accessible for disabled people

In order for sanitary facilities to meet the tasks set for them, they must meet a number of requirements. They must be designed and manufactured so that they can be used properly and for a long time. They should be functional, durable and well-constructed. In addition, they should be available in different styles, and the color palette should be wide. This need is related to the fitting of sanitary facilities to the different tastes of bathrooms and kitchens users.

An important feature of plumbing fixtures is their attractive appearance.

The development of the sanitary branch and access to more and more modern materials allows contemporary manufacturers to exceed the existing borders in design.

Their utility and accessibility for disabled people are also important.

# Requirements for plumbing fixtures

Their utility and accessibility for disabled people are also important.

In 1992, the Americans with Disabilities Act (ADA) was passed in the United States to provide greater access to public and commercial buildings for people with disabilities:

- providing adequate maneuvering space
- doors for the disabled, i.e. those that have no thresholds, and whose minimum width is 0.9 m
- special handles and handrails for disabled persons
- installing in the restroom at least one toilet for the disabled and a washbasin for the disabled

# Requirements for plumbing fixtures
## Toilets for people with disabilities

The recommended height of the bowl is 45–50 cm; as a standard it is 40 cm.

This is the height of the upper edge of ceramic sanitary equipment (plumbing fixture) – measured from the floor.

The level of the toilet bowl and the level of the wheelchair seat should be the same.

special handles and handrails for disabled persons

distance from the toilet bowl to the back wall

# Requirements for plumbing fixtures

## Toilets for people with disabilities

- The wheelchair is freely placed along the bowl

a room of area of 100 $m^2$ and 4 m high

The distance of the toilet for the disabled from the back wall should not be less than 70 cm. This ensures that the wheelchair to be freely placed along the bowl.

# Requirements for plumbing fixtures

## Toilets for people with disabilities

The photograph shows another example of a toilet for disabled people.

# Requirements for plumbing fixtures
## Lavatories for people with disabilities


The picture presents the main features of a washbasin for disabled people. These are the shape of a plumbing fixture (shallow bowl) and the special type of faucet (with wrist-blade handles).

# Plumbing fixture material

- durable
- Corrosion-resistant

Health requirements for plumbing fixture material

- smooth
- non-absorbent
- free from concealed fouling surfaces

Sanitary facilities are manufactured from durable and corrosion-resistant materials.
Due to health requirements, material of plumbing fixture should be smooth and non-absorbent. It should not have concealed fouling surfaces. These features of material will allow sewage to be completely removed by flowing water.

# Plumbing fixture material

Materials used to manufacture plumbing fixture are:

- vitreous china/porcelain
- vitreous faience
- marble
- enamelled cast iron
- enamelled plate
- stainless steel
- fiberglass
- plastics – plastic resin, acrylic
- composites and conglomerates ("cast marble", CORIAN®, STARON®,  Kerrock, other).

# Plumbing

The pictures show plumbing fixtures (a toilet bowl and a washbasin) made of stainless steel. They constitute the equipment of a public toilet near a motorway (passenger service area).

# Plumbing

The pictures present plumbing fixtures (a bidet and a washbasin) made of vitreous china.

# Plumbing fixture material Corian®

More interesting materials from which plumbing fixtures are made include composites and conglomerates.

CORIAN® is the trade name of DuPont. This material has been known on the market since 1967. Plumbing fixtures are produced by casting or thermoforming.

This material consists of about 1/3 acrylic resin (also known as poly(methyl methacrylate) or PMMA), and about 2/3 natural minerals. These minerals consist of aluminum hydroxide derived from bauxites.

It is a mixture of minerals with an adhesive from an acrylic resin.

*Source: plastics.pl/produkty/budownictwo/umywalki-i-zlewy-corian*

# Plumbing fixture material Corian®

This material has a number of advantages.
It is:

- nonporous
- durable
- hygienic and non-toxic
- thermoformable
- sublimation susceptible
- completely neutral for the natural environment
- resistant to UV rays
- renewable and easy to repair.

*Source: plastics.pl/produkty/budownictwo/umywalki-i-zlewy-corian*

# Plumbing fixture material Silestone®

Silestone is an industrial conglomerate (as traders call it)  of quartz and polyester resin that is characterized by very good physical and chemical properties. This material is resistant to various types of acids, it does not stain and discolor. It is also very resistant to mechanical damage – impacts and scratches.

- quartz and polyester resin
- bacteriostatic protection
- resistance to acids
- stain resistance
- impact resistance
- scratch resistance
- a wide range of colors
- various surfaces

*Source: silestonepolska.pl/showroom/zlewozmywaki*

# Composite vs. conglomerate

The comparison above is of the basic differences between composite and conglomerate.

- composite
- Trade marks:

CORIAN®, STARON®, Kerrock

- a mixture of minerals with an acrylic resin adhesive
- conglomerate (synthetic stone)

SILESTONE®

- stone aggregate (quartz aggregate) bonded with polyester resin

# Lavatory washbasin

- used to wash the hands and face, and for brushing teeth
- sometimes used for foot washing
- installed in bathroom, restrooms (bathroom in a public building)
- installed sometimes in guest rooms, hotel rooms
- their size is adapted to the assignment

Lavatories are made from different materials. These are: vitreous china, vitreous faience, enamelled cast iron, marble, glass, stainless steel, acrylic plastics, ABS, composite (CORIAN®), wood.

# Models of lavatories

Wall – hung

- Raised back
- Ledge
- Pedestal, semi pedestal/half pedestal

Countertop

- SELF – RIMMING (let in the top)
- Undercounter
- Overtop (standing)
  - ✓ Vanity top (standing), furniture washbasin

Raised back washbasins support themselves better (than ledge washbasins) since they have more bearing surface on the back.

# Lavatories

The picture at the left presents a ledge, wall-hung washbasin. The picture at the right presents a raised back, wall-hung washbasin.

# Lavatories

The picture presents a pedestal lavatory. It is a two-piece plumbing fixture. It consists of a washbasin and a pedestal base.

# Countertop

Undercounter

Self-rimming

In self-rimming lavatories, the bowl is placed in the opening of the countertop and the edge of the fixture rests directly on top of the countertop.
In undercounter lavatories, the bowl is attached to the underside of the countertop.

# Countertop

Vanity top

It is a one-piece washbasin and countertop installed on top of the cabinet.

# Countertop – overtop


Another model of lavatory, which can be considered as a countertop type, is that of the washbasin standing on the countertop. It is situated overtop the counter.

# Industrial/commercial-use washbasins


The pictures present lavatories in commercial/industrial applications in a cosmetician's shop. The image on the left shows a marble basin for pedicures, and the image on the right shows a washbasin used to prepare a manicure.

# Industrial washbasins

The pictures show lavatory in commercial/ industrial applications in a hairdresser's. The image on the left shows a washbasin for washing the head, while the image on the right shows the faucet for it.

# Bathtub

- used to bathe the entire body
- installed in a bathroom in which is possible to bathe
- rectangular, corner, other shapes
- typical lengths are 1.0–1.7 m
- for one or more persons

# Bathtub material

- enamelled cast iron
- enamelled pressed steel
- fiberglass
- stainless steel
- acrylic plastics
- marble
- composite
- wood, cooper

# Designs of bathtubs

- RECESSED

permanently attached or built into the walls and floor of the bathroom

- FREESTANDING

supported by legs, not permanently attached to the bathroom walls or floor

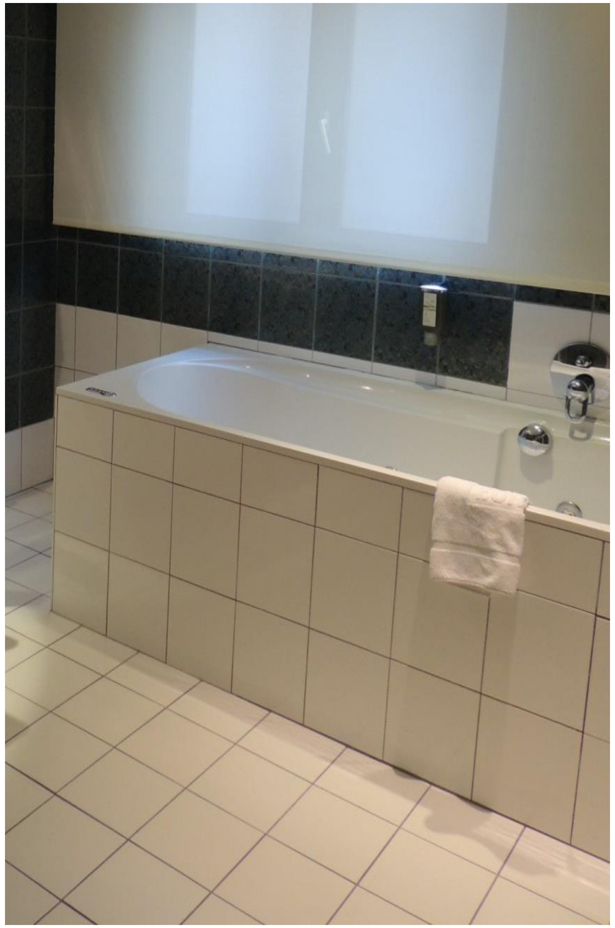
- DROP-IN

installed in enclosure

# Designs of bathtubs

Freestanding

Recessed

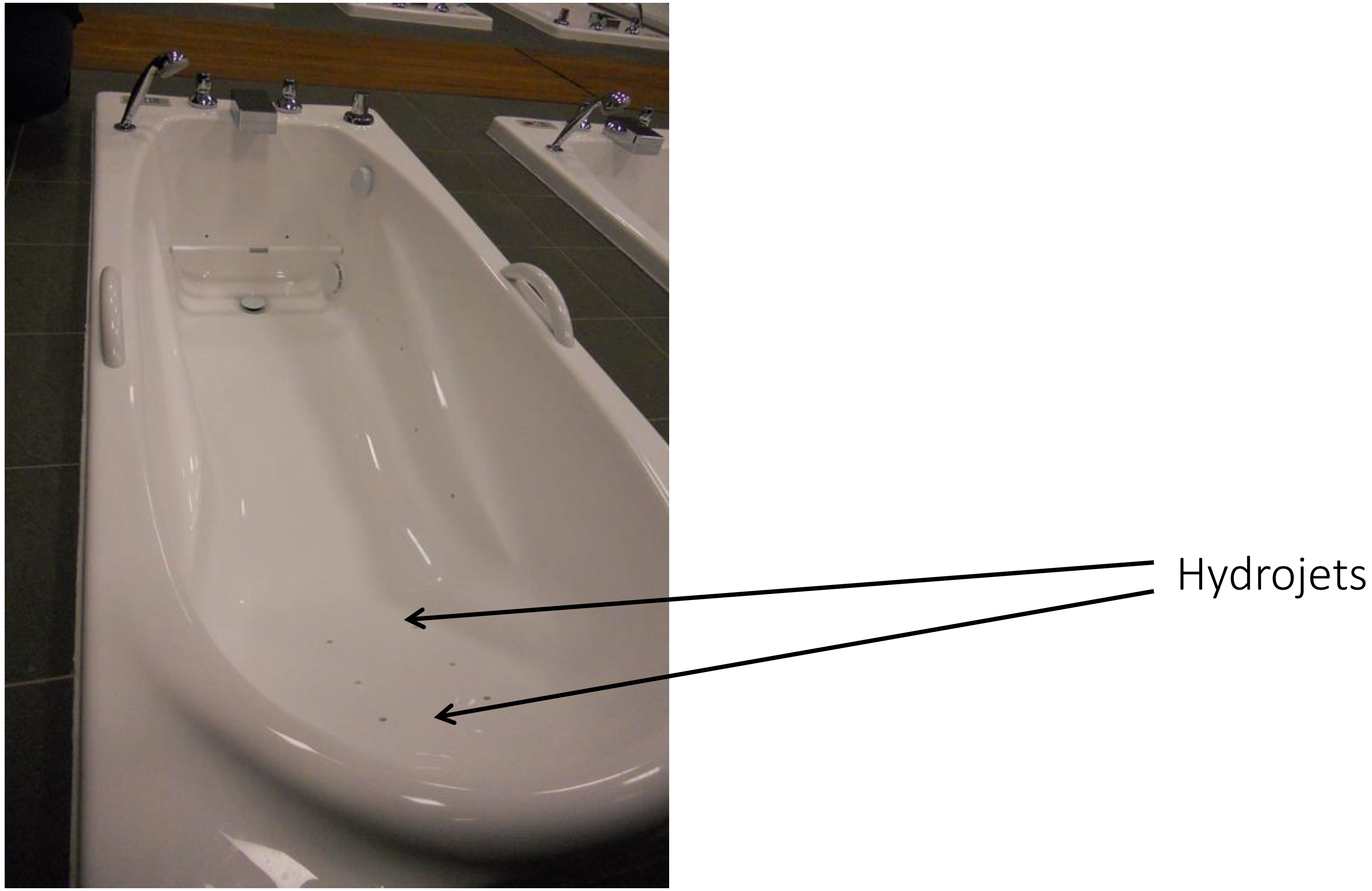


The pictures present different models of bathtubs.

# Whirlpool bathtub

- equipped with water and air circulation equipment
- used to bathe and massage the entire body
- hydrojets provide massaging action
- hydrojets are positioned along the sides and ends of the bathtub

# Whirlpool bathtub




The photograph shows the whirlpool bathtub. The hydrojets are indicated.

# Bathroom for footballers
## National stadium Warsaw


The photograph at the right shows special example of use of plumbing fixtures. There are multiple whirlpool bathtubs in one room. It is special bathroom for footballers and is situated at the National Stadium in Warsaw, Poland.

# Shower

## Shower bath

- discharges water from above a person who is bathing
- receptacle that allow water to accumulate in them (shower base)
- single – showerhead installations (used in residential buildings)
- series of showerheads for shower rooms (schools, fitness facilities)

# Showers for footballers

The photograph presents a  series of showerheads. It is shower room for footballers and is situated at the National Stadium in Warsaw, Poland.

# Shower enclosure

- **one – piece prefabricated assemblies**

only in new construction, eliminate potential leaks

- **multipiece prefabricated assemblies**

consist of SHOWER BASE and WALL PANELS

may leak at joints between the walls and the shower base

- **ceramic tile shower baths**

SHOWER BASE or waterproof membrane

may be constructed in almost any shape and size to fit available space

# Shower materials

- fiberglass (shower base)
- acrylic (shower base)
- tempered glass (shower door, wall panels)
- ceramic tile
- waterproof rubber membrane

# Shower in a guest room

The picture presents an example of a shower in a guest room (for 4 persons) in Great Britain. The shower enclosure is situated in the room, next to the marble chimney.

# Ceramic tile shower bath shower base

The pictures show the use of ceramic tile in a shower bath (at the left) and for a shower base (at the right).

# Ceramic tile shower bath

The picture presents another example of the use of ceramic tile for a shower stall.

# Bidet

- used to bathe external genitals and posterior parts of the body and provide relief for certain health conditions (e.g. haemorrhoids)
- (used for washing one's genital and anal area)
- used for washing feet
- consist of a low (oval) basin supplied with hot and cold water and a drain equipped with a pop – up waste fitting
- with or without bidet seat

Bidets materials

- vitreous China
- vitreous faience

# Bidet

contemporary

30 years of the 20th century

*Photo by J. Bąk*

The pictures presents two bidet types. One is designed in accordance with contemporary design, the other is  from the 1930s. The second photograph was taken in the Prague Waterworks Museum.

# Bidet


The picture presents bidet trim. It includes a single handle faucet that controls the cold and hot water supply and the pop-up waste fitting.

# Bidet seat

*Source: roca.pl/katalog/produkty/bidety/deski-bidetowe/gap/pokrywa-bidetu-wolnoopadajaca-zalecana-bidetu-stojacego-gap-w-przypadku-kompletacji-z-wc-kompakt-rimless-806472..4#!A806472004*

# Washing toilet

- water closet with toilet seat with the function of washing and drying

*Source: roca.pl/katalog/produkty/toalety-myjace/in-wash/inspira/in-wash-toaleta-myjaca-typu-kompakt-zasilanie-230v-803061..1#!A803061001*

# Bidetta

- is the name of a special shower head, the size and flexibility of which are adapted to the close fitting to the toilet bowl

# Bidetta

The picture presents  a water closet with a bidetta.

*Source: lazienkaplus.pl/pl/blog/higiena-w-toalecie-na-3-sposoby-bidet-bidetta-czy-toaleta-myjaca-170/*

# Kitchen sink

- shallow
- flat – bottomed
- used to clean dishes and prepare food
- has up to three basins (multibasin sink)
- without or with the possibility of collecting water in them

# Kitchen sink trim

Kitchen sink trim includes a faucet with a swing spout, and kitchen sink drain fittings.
The single swing spout allows to supply water to more than one basin.
A basket strainer is a drain fitting installed in a kitchen sink.

Kitchen sink materials:

- enamelled cast iron
- enamelled pressed steel
- stainless steel
- acrylic
- composite
- conglomerate

# Models of kitchen sinks

- SELF-RIMMING

the basin is placed in the opening in the countertop and the edge of the fixture rests directly on top of the countertop

- UNDERCOUNTER

the basin is attached to the underside of the countertop

# Self-rimming

The picture shows an example of a self-rimming kitchen sink with one basin.

# Water closet toilet

Water flushed plumbing fixture that receives human liquid and solid waste in a water – containing receptacle, and upon flushing, conveys the waste into a soil pipe.
A large bowl for urinating or defecating into, typically plumbed into a sewage system and with a flushing mechanism.

# Water closets materials

- non porous material
- not absorbs odours
- easily cleaned
- vitreous China
- stainless steel

# Design of water closets

- siphon jet water closet
- gravity – fed water closet
- blowout water closet
- with a shelf (residential construction)
- floor – set (residential construction)
- wall – hung (commercial construction)

Currently, a toilet with a shelf is a rare solution, although medical doctors consider it a good solution for households as it enables the monitoring of the user's health.

# Flush devices

- flush tanks (toilet tanks), flushing cistern
- pressure tanks
- flushometer valves

They are designed to deliver a proper amount of water to the water closet bowl and provide necessary scouring action to clean the bowl.

# Flush devices

The pictures present examples of flushometer valves used for water closets.

# Design of water closet bowl

- elongated (commercial, public buildings)
- round front (plain bowl) – residential construction

# Water closet configurations

Floor-set

Wall-hung

The pictures show two different configurations of water closets.

# Urinal

- receives only liquid body waste
- convey the waste through a seal trap into a sanitary drainage system

Various flushing action:

- washout (stall, wall-hung, trough)
- blowout (wall-hung)
- siphon jet (wall-hung)
- waterless

# Models of urinal

Various models of washout urinals:

- stall
- wall-hung with integral P-trap
- wall-hung with exposed trap
- trough

A stall urinal is a plumbing fixture that is installed with the lip slightly below the floor level.

# Urinal

Urinals are flushed with MANUAL or ELECTRIC sensor flushometer valves to deliver water to the fixture for waste removal.

Urinal materials:

- smooth
- non-absorbent
- vitreous china
- enamelled cast iron
- stainless steel

# Wall-hung urinal

The picture presents a wall-hung urinal.

# Floor drain

- cast iron or plastic
- plumbing fixture set flush with a finished floor
- used to receive water drained from the floor and convey it to a drainage system
- with or without P-trap
- dry pan (garages and other areas subject to freezing)

# Floor drains

removable grate

The pictures present examples of floor drains.

# Food waste disposer garbage disposal

- electric appliance supplied in water from kitchen sink faucet
- grind food waste into pulp
- discharge the pulp into the drainage system
- mounted below a kitchen sink basin

# Dishwasher

- electric appliance used to wash dishes
- domestic dishwasher wastewater is pumped out of the appliance into the kitchen sink waste pipe (or food waste disposer tailpiece)

# Professional dishwasher

- restaurants usually require several dishwashers
- dishwashers for glass are configured differently than  dishwashers for porcelain or dishwasher for pots
- dishwashers for kitchen accessories require high water jet strength

# Washing machine

- a machine for washing clothes, bed linen and other items
- freestanding
- built-in (into cabinet)

# Drinking fountain

- wall-hung or freestanding plumbing fixture
- delivers a stream of drinking water through the nozzle at an upward angle to permit the user to conveniently drink from the fountain
- installed in public areas (hallways, schools)
- installation in restrooms is prohibited (for sanitary reasons)

# Water cooler

- wall-hung appliance
- incorporates an electric cooling unit into a drinking fountain
- provide cooled drinking water at a desired temperature
- the temperature of water is reduced before delivering it to the nozzle
- ideal temperature for drinking water is 10°C
- installed in public areas (hallways, schools)
- installation in restrooms is prohibited (for sanitary reasons)

# Drinking fountains



The pictures present various models of drinking fountains from the trade fairs. The images on the left show a wall-hung drinking fountains, and the image on the right presents a free standing drinking fountain.

# Drinking fountains

The pictures present a free standing drinking fountain and the principle of using it. This plumbing fixture is located in the complex of indoor pools in a hotel.

# Water cooler


The picture presents example of a water cooler. The photograph was taken at a trade fair.

# Other plumbing fixtures

SERVICE SINK/SLOP SINK

- high back sink with a deep basin used for filling and emptying scrub pails, rinsing mops, disposing of cleaning water
- enamelled cast iron

MOP BASIN/MOP RECEPTOR

- floor-set basin used for cleaning and other maintenance tasks
- fiberglass or enamelled cast iron

# Other plumbing fixtures

LAUNDRY TRAY/LAUNDRY TUB

- used for prewashing clothes
- installed in residential laundry room
- wall-hung or floor-set

# Other plumbing appliances

## WATER SOFTENERS

Plumbing appliance that removes dissolved minerals such as calcium and magnesium from water by an ion exchange process.

## WATER FILTERS

Plumbing appliance that removes sand, sediment, chlorine, lead, other undesirable elements from water

- in-line
- point of use

# Other plumbing appliances

WATER HEATERS

- Incorporate limiting controls for heating water up to 99°C
- Gas water heaters (with storage tank)
- Electric water heaters (with storage tank)
- Tankless water heaters (electric or gas-fired)
- Point of use water heaters

# Faucets

- control the cold and hot water supply
- classified as:
  - ✓ Compression faucets (two-handle mixer)
  - ✓ Port control faucets (single-handle faucets)

Faucet materials

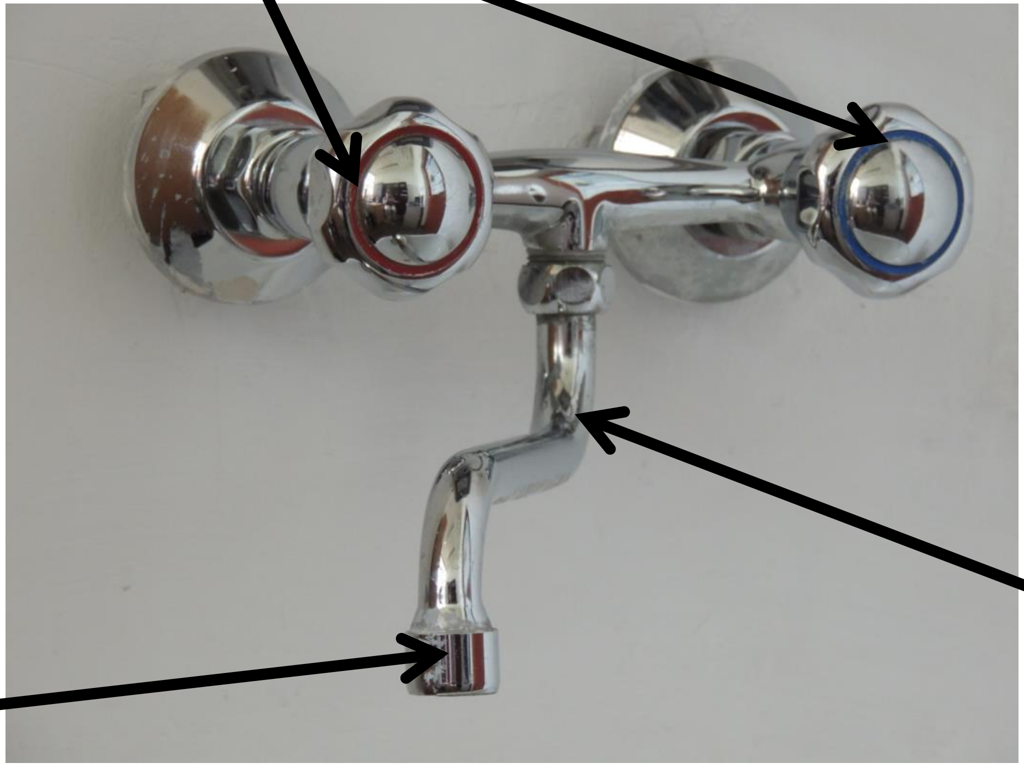
- brass
- stainless steel
- plastic
- zinc

# Compression faucets

- the flow of water is shut off by means of a washer that is forced down (compressed) onto its seats, as with the globe valve
- most compression faucets are combination faucets in which the cold and hot water compression valves are joined in one faucet body and provided with a common mixer spout.
- allow to mix hot and cold water to the desired temperature prior to the water being delivering to the lavatory

It is a faucet in which the flow of water is shut off by means of a washer that is forced down (compressed) onto its seats, as with the globe valve.

# Compression faucets




The picture presents basic elements of a compression faucet.

# Single-handle faucet port control faucet

- single-handle
- noncompression faucet that contains ports for the hot and cold water supply and a cartridge or ceramic disc that opens and closes the ports as the faucet handle is moved or rotated
- single handle controls the flow of hot and cold water by using a disc/cartridge to open and close ports in the faucet

# Cascade faucet (sprinkle faucet)

The pictures show the example of a cascade faucet.

# Electronic faucet

- in public restrooms
- conserve water
- for hygiene
- has a solenoid valve that is activated when the user places their hands under spout

# Types of faucet

- Deck-mounted
- Wall-mounted
- 1 handle
- 2 handle

Washerless faucets:

- ball
- disc
- cartridge

# WashUP

"WashUP" is a conceptual design which integrated a washing machine with toilette-flush. It allows for sustainable water consumption by storing the waste water from washing machine in a flush tank and reusing it when flushing the toilet.  A washing machine is fixed on wall upwards of the water closet.

*Source: wowtec.wordpress.com/2013/02/24/high-tech-washup-by-sevin-coskun/*

# Integrated plumbing fixtures

In the picture, the washbasin is integrated with the urinal. The photo was taken at a trade fair.

# Part 8

# *Water plumbing installation*

*Joanna Bąk*

# OUTLINE OF THIS PART:

Introduction
Plumbing fixtures and appliances
- definitions
- requirements
- materials

types and models
- examples

Sanitary fittings – tap fittings
Low – flow plumbing fixtures and appliances
Waterless fixtures
Unusual plumbing fixtures

This part is divided into several parts. The first of these is "Introduction". The following sections present the characteristics of plumbing fixtures. In particular, these are basic definitions, requirements for them, types and models, and materials used in its production. Examples of various models of the sanitary facilities discussed are also shown. The tap fittings are presented in a separate part of lecture. The next part of lecture refers to low-flow plumbing fixtures and appliances and waterless fixtures. They are only mentioned because they are given in a separate lecture about sustainable plumbing.

In the final part of the lecture, examples of atypical and unusual sanitary devices, such as washing machines integrated with toilette, are indicated.

# Water installation systems in builidings

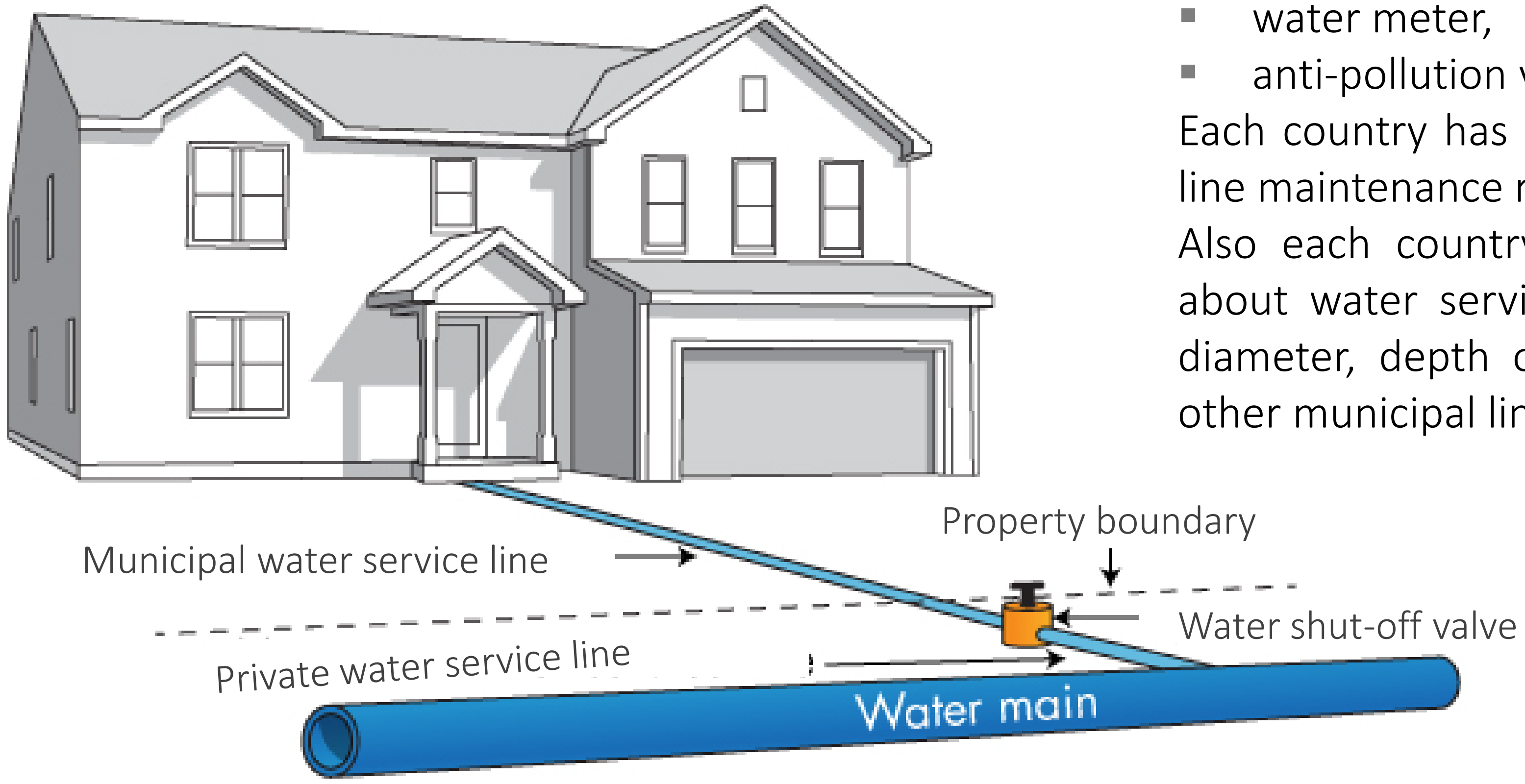
**Residential and public buildings:**
Drinking water systems
Fire protection systems
Dual piped water supply systems (potable and non-potable water)

**Industrial facilities:**
Drinking water systems
Technology water systems
Fire protection systems

# Water service line

- A water service is defined as the piping that connects a property or building to a municipal water main
- It is an underground pipe to supply water from the water main to the building
- A typical water service consists of municipally-owned piping (municipal water service line) and privately owned piping (private water service line)

# Water service line




The water service line equipment include:

- cut-off valves,
- water meter,
- anti-pollution valves.

Each country has own regulations about water line maintenance responsibility issues.

Also each country has its own requirements about water service line's pipe material, min. diameter, depth of the line, min. distance to other municipal lines.

The picture presents elements of the water service line.

*Source: utilitieskingston.com/Water/frozenservices/Defined*

# Water service line

- the minimum diameter is 25 mm
- minimum slope from the building towards the external network – 3‰
- piping of water service line outside the building should be run at a depth ensuring that the pipe is covered with a layer of ground with a height of 0.4 m greater than the depth of freezing of the ground for a given zone

# Water service line regulations in Poland

Building shall be connected to the water main by a single service line.

Two water service lines are allowed for hospitals and army facilities.

# Water service line connection

1) Tee fitting is used when:
   - the service line's diameter is larger than 50 mm

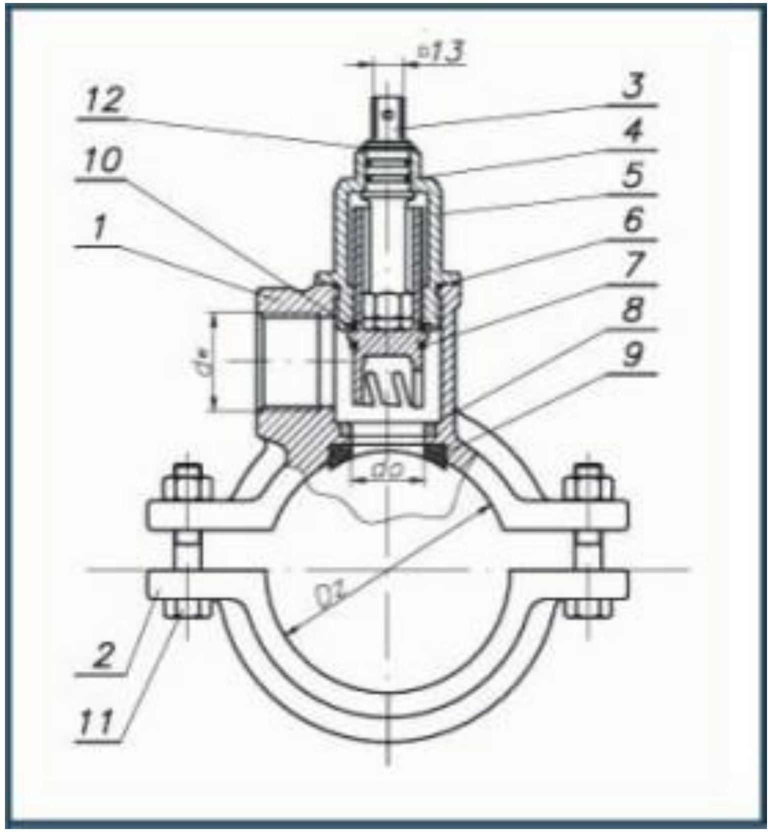
$$\frac{D_{service\ line}}{D_{water\ main}} > \frac{2}{3}$$

While connecting the water service line to the water main, it must be shut down.

- for newly built water supply networks

2) Pipe drilling saddle – used to connect the building to the water main. No water main service interruption must take place.
   - The service line's diameter is much smaller than the water main's
   - The water service line's diameter is smaller than 50 mm

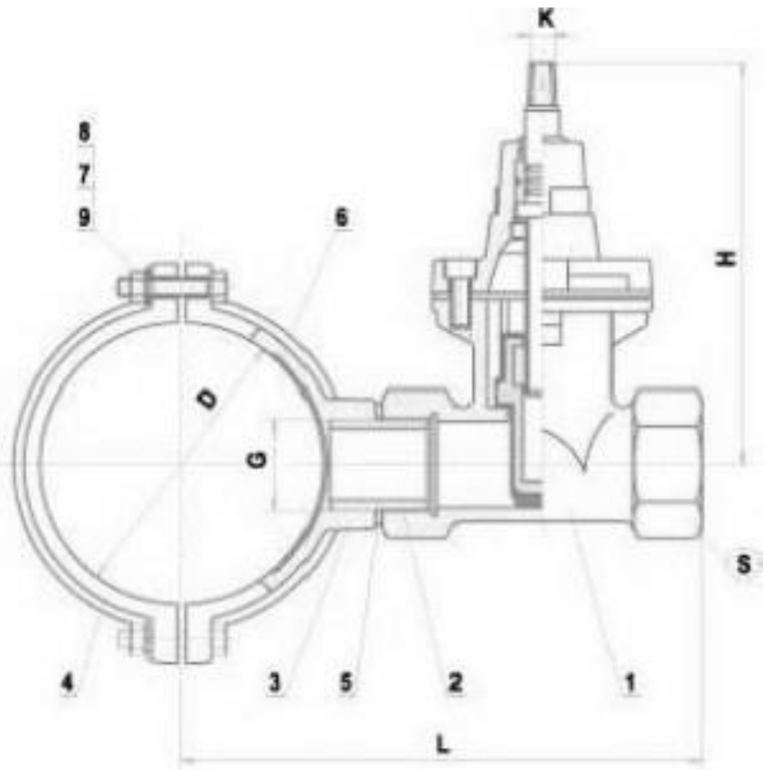
# Water service line connection




The pictures show an example of a pipe drilling saddle.

*Source: instalacje.gep.com.pl/przylacze-wodociagowe/*

# Water service line connection

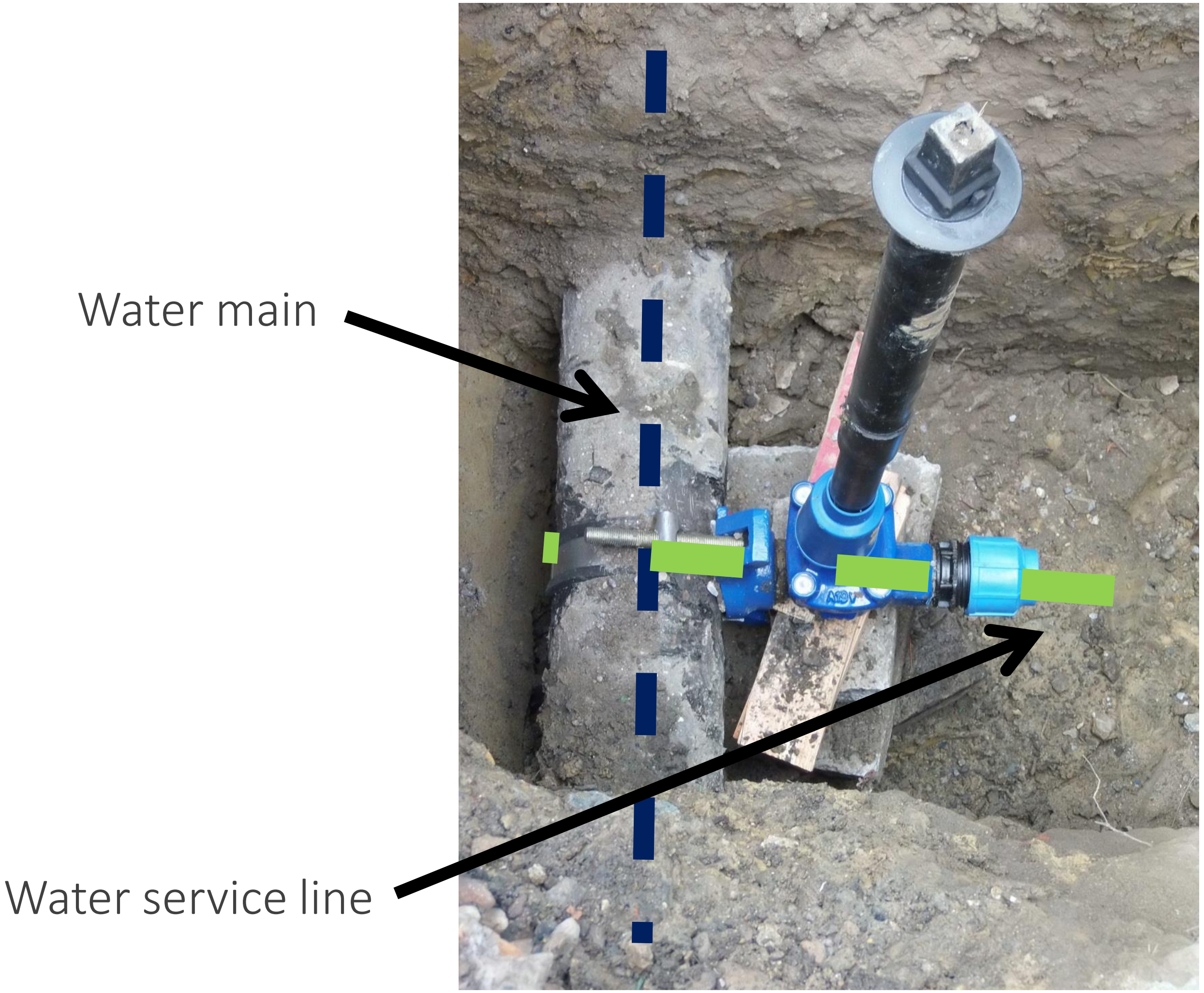



The pictures show an another example of a pipe drilling saddle.

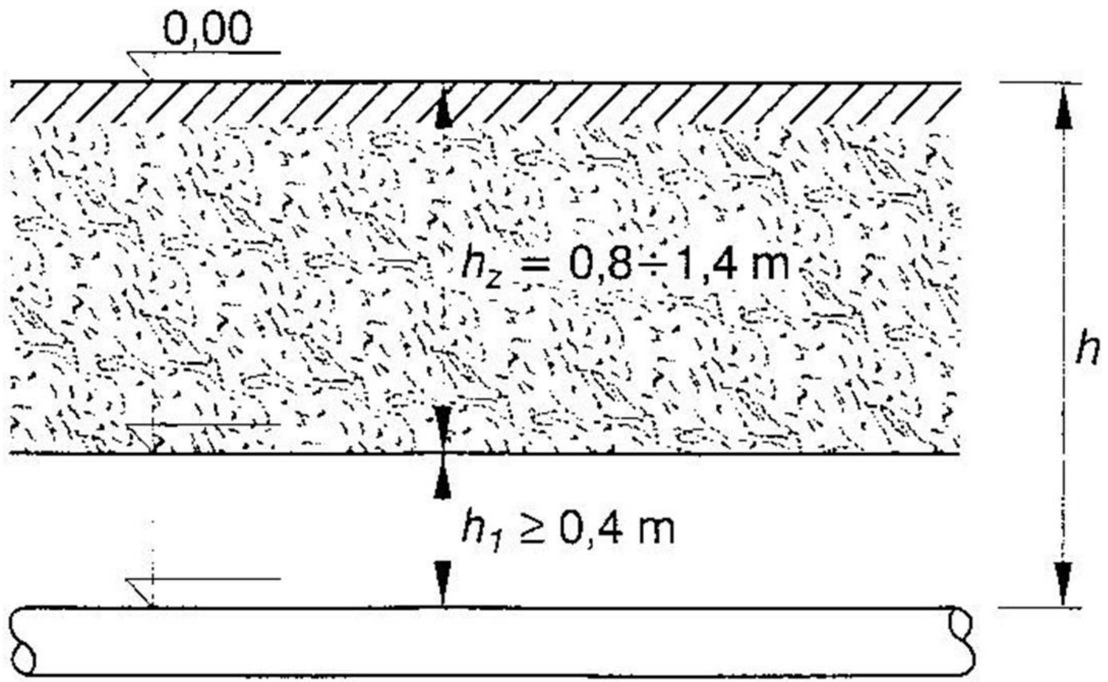
*Source: instalacje.gep.com.pl/przylacze-wodociagowe/*

# Water service line connection

The photograph presents water service line connection to the water main.
The curiosity is that the water main is an asbestos-cement pipe.
The connection will supply water to a single-family house.



# Depth of water service line




The scheme presents the depth of water service line.
$h_z$ – depth of the ground freezing zone
In Poland, there are four ground freezing zones. They range from 0.8 m to 1.4 m.

*Source: Chudzicki, Sosnowski, 2011.*

# Location of water service line

This page gives the requirements which are applicable in Poland.
Minimum distances from parallel pipes of other installations are:

- 1.5 m from the sewage connection and gas connection
- 0.8 m from power cables
- 0.5 m from telecommunications cables

At the crossing of the water service line with the sewage pipe at a distance of less than 0.6 m, a protective pipe should be placed on the water supply pipe.
Above the connection pipe (water service line) at a distance of 0.3 m, **identification tape** of blue or white and blue with a double steel strip should be placed.

# Water service line

SLOPE: a minimum of 3 ‰ in the direction of the water pipe (for draining the section)

MATERIAL:

- **galvanized steel** (small diameters)
- **ductile iron** (larger diameters DN 80, 100 and 150 mm)
- (grey cast iron)
- **plastics** (small and larger diameters)
  - ✓ PVC, PVC-U, PVC-C,
  - ✓ PE, HDPE, MDPE, LDPE

# Materials – inner installation

- Steel
  - ✓ Galvanized steel
  - ✓ stainless steel
- Copper

# Materials – inner installation

- Plastic
  - ✓ PVC, PVC-U
  - ✓ CPVC (Chlorinated Polyvinyl Chloride)
  - ✓ PE (HDPE, MDPE, LDPE)
  - ✓ PE-X (cross-linked polyethylene)
  - ✓ PP PP-R
  - ✓ PP-RT
  - ✓ PB
  - ✓ PE–Al.-PE, PE-X-Al.-PE-x
  - ✓ ABS (Acrylonitrile – Butadiene – Styrene)

# Water meters

- A water meter measures the flow velocity and indicates the volume of water used
- Meter selection is based on the nominal and maximum flow rates
- Measurement accuracy depends on the metrological class and meter’s position, which might be horizontal or vertical
- Some water meters are adjusted for remote reading

Adjustation to remote reading of water meters is a significant trend in modern measurement techniques.

# Water meters

There are many classification principles for water flow meters. Classification is according to:

- measurement principle,
- measurement method and structure form,
- measurement purpose (residential/industrial),
- measurement medium (cold/hot water),
- measurement pipe diameter (small and large diameter; 40/50 mm),
- indication value display mode.

# Water meter


The photographs present an example of a water meter. The colour of the housing indicates the type of medium (hot or cold water) which is measured.

# Water meters

According to the measurement principle is a major classification method. Generally can be divided into velocity type water meter and volume type water meter.

1) Velocity water meter
2) Volumetric water meter

Installed in a pipeline, consisting of a chamber of known volume that is filled and discharged one by one, and a water meter that is fluid-driven, or is a quantitative discharge meter.

# Velocity water metres

- Installed in a closed pipe, consisting of a moving element,
- Typical velocity water meters are rotary-wing water meters and screw-wing water meters. The rotary vane wheel-type water meter is divided into a **single-flow water meter** and a **multi-flow water meter**.

# Water meters

- Classification by metering level

The metering level reflects the working flow range of the water meter, especially the metering performance at small flow rates. According to the order from low to high, it is generally divided into A-class, B-class, C-class, and D-class, and its measurement performance meets the corresponding requirements of the measurement registration A, B, C, and D levels specified in the national standards.

Watermeter set:
Valve, Watermeter, Valve, Antipollutant valve

# Water pressure

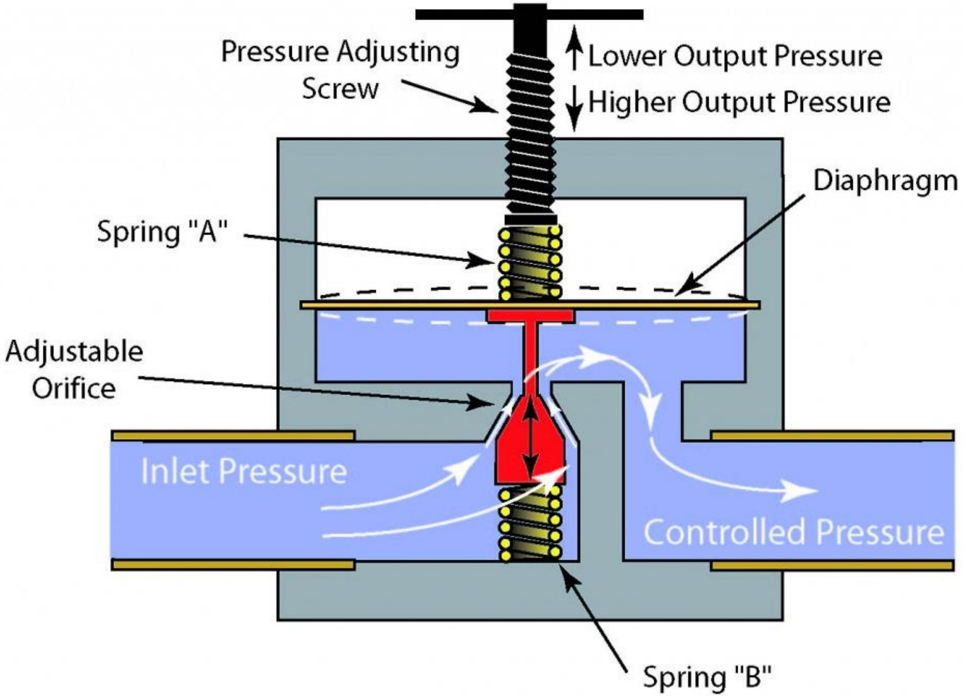
One of the key factors determining the water service quality.
The pressure in the installation should not exceed 0.6 MPa and should not be less than 0.05 Mpa (5 meters of water column to 60 meters of water column).

**High water pressure may lead to:**
Excessive flows at fixtures and waste of water
High velocities with a resultant noisy piping system
Failure of piping joints, fixtures and appliances

**Solution:** Pressure reducing valve installation

# Pressure reducing valve

- Decreases the outlet water pressure to a determined value




A diaphragm flexes in response to the pressure on the outlet side of the valve. This diaphragm is attached to the moving part of a variable orifice valve. The movement of the diaphragm is counteracted by two springs and an adjustable screw to adjust the output pressure. The picture shows the principle of functioning of a pressure reducing valve.

*Source: techblog.ctgclean.com/2012/04/valves-pressure-reducing-valves/*

# Water pressure

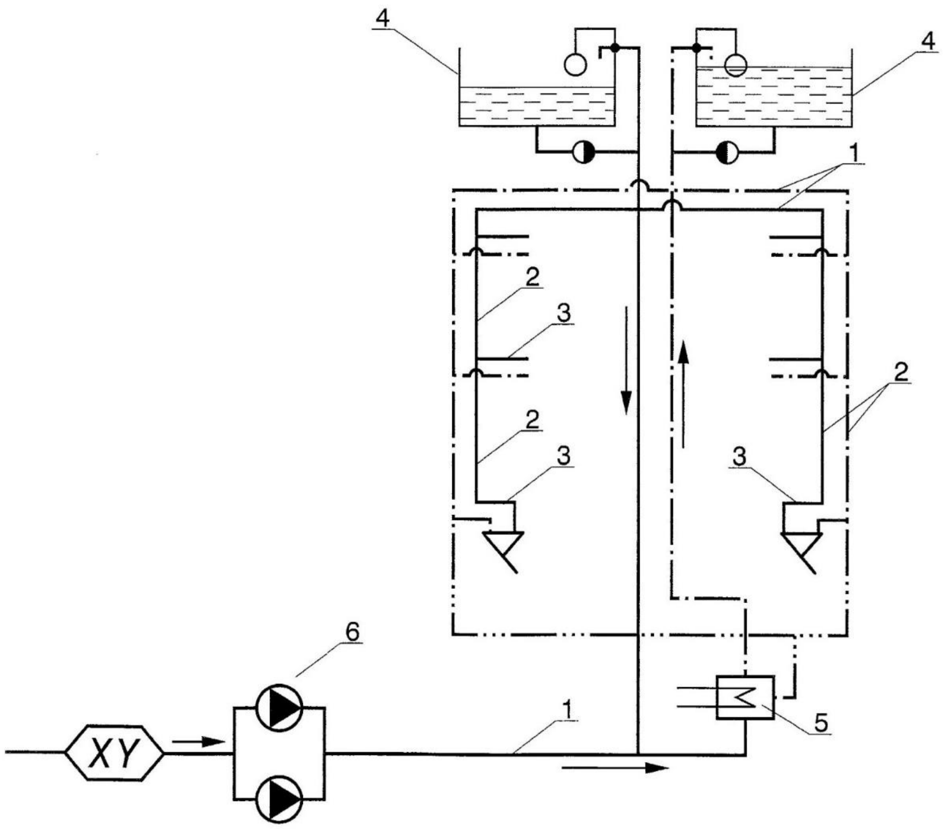
- Insufficient water pressure does not ensure proper operation of water appliances and plumbing fixtures
- It might occur in multi-storey buildings or when water main pressure is too low.

Solution: pressure booster installation

# Multi storey buildings

- Systems can be up-fed or down-fed
- Multi-storey buildings can usually be divided into zones of water pressure control
- The lower two to three storeys can generally be supplied directly from the pressure in the public water main
- Upper storeys, usually in groups of five to eight storeys, can be supplied from pressure-boosted main risers through a pressure reduction valve for each group

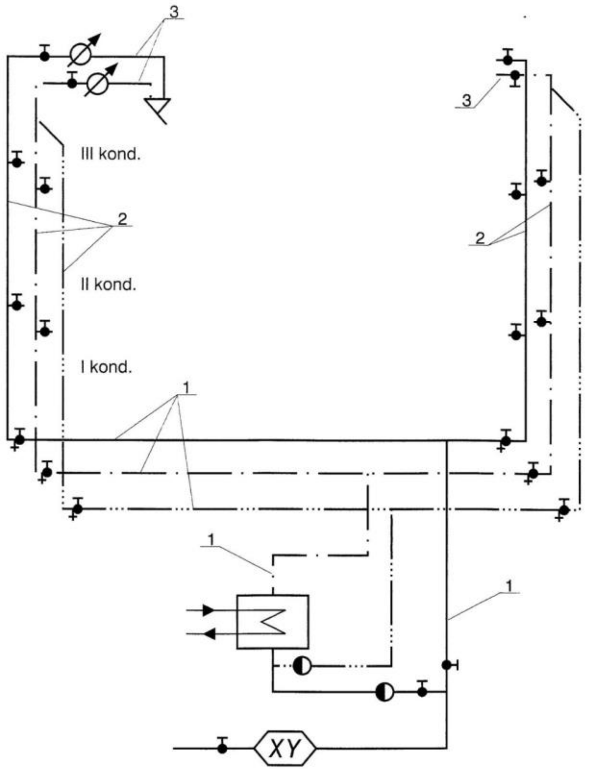
# Up-fed water installation system




The scheme presents an up-fed water installation system.

*Source: Chudzicki, Sosnowski 2011*

# Down-fed water installation systems




The scheme presents a down-fed water installation system.

*Source: Chudzicki, Sosnowski 2011*

# Hot water installation

1. Source of hot water
   a. Direct fired heaters
      - Electric
      - Oil or gas fired
   b. Indirect heaters

Heat source is remotely located – heat exchanger

2. Storage of hot water
   - Storage type water heaters
   - Instantaneous type heaters
   - Semi-instantaneous type heaters

When using boiler combustion, proper room ventilation is required

Often applied in multi family housing, when heat is supplied from the heating plant.

# Pipe insulation

Reason:

- **Condensation control** – applied when the pipes operate at below-ambient temperatures to prevent the condensation of water vapor on the pipe surface
- **Heat loss prevention** – applied for hot water pipes to save Energy to prevent cold water temperature increase
- **Pipe freeze protection** – applied to pipes in unheated areas, when the temperature drops below 0°C

# Temperature change results in pipe length change

$$\Delta L = \alpha \cdot L \cdot \Delta t, \text{ mm}$$

$\Delta L$ – thermal expansion/contruction, [mm]
$\alpha$ – linear expansion coefficient, [mm/m,K]
$L$ – pipe length, [m]
$\Delta t$ – temperature difference between ambient temperature and operating temperatures, [K]

# Expansion loops

It is a common way to absorb the temperature expansion in pipes. Expansion loops can be fabricated from standard pipes and elbows:

- Full loop
- Horse shoe (lyre loop)

# Pipe protection sleeves

It is a fixed cylindrical insert that is located where the pipe is to pierce a slab. It should pass completely through the partition and extend 2 cm above the surface and 1 cm below it.

The protection sleeve inner diameter should be:

- min. 1 cm higher than pipe's external diameters when crossing a floor
- min. 2 cm higher than pipe's external diameters when crossing a wall

It should be extended 2 cm both sides of the wall.

# Calculation methods

Calculating the calculation flow for plumbing:

- according to the PN-92/B-01706 method
- according to the method PN-EN 806-3:2006 (simplified method)
- according to the Brix method (German method)
- according to the Spysznow method (Russian method)

# Calculation flow general model PN-92/b-01706

$$q = A \cdot \left(\sum q_n\right)^k - B$$

where:

*A*, *B*, *k* – coefficients depending on the type of building, fittings and the sum of normative outflows from drawing points

$q_n$ – normative outflow of water [$dm^3/s$]

# According to the method PN-EN 806-3: 2006 (simplified method)

- 1 loading unit (LU) is equivalent to a draw – off flow rate QA of 0.1 l/s
- beginning at the last draw – off point, the loading units for each section of the installation have to be determined
- the loading units must be added

# According to the method PN-EN 806-3: 2006 (simplified method)

- depending on the material chosen by the designer, the pipe size can be taken out of tables from the norm
- tables exist for hot dip galvanized steel, stainless steel, copper, PEX, PB, PP, PVC – C, multilayer pipes

# Hot – dip galvanized steel

The table according to the PN-EN 806-3: 2006

| Maximum load | Diameter DN | Inner diameter Di |
|---|---|---|
| LU | mm | mm |
| 6 | 15 | 16 |
| 16 | 20 | 21.6 |
| 40 | 25 | 27.2 |
| 160 | 32 | 35.9 |
| 300 | 40 | 41.8 |
| 600 | 50 | 53 |
| 1,600 | 65 | 68.8 |

# National pipe sizing methods

- Austria
- Denmark
- Finland
- France
- Germany
- The Netherlands
- Spain
- United Kingdom

Poland (?)

# Maximum flow velocities

- Header pipes, rising pipes, floor service pipe: max 2.0 m/s
- Connection pipes to one fitting (dead legs): max 4.0 m/s

National regulations may require lower flow velocities to avoid water hammer and noise.

# Part 9

# *Sewage installation*

*Joanna Bąk*

# OUTLINE OF THIS PART:

- Introduction
- Characteristics and principles of designing of elements of sanitary drainage system:

FIXTURE DRAIN

STACKS

SEWER SERVICE LINE

- Materials
- Hydraulic calculations of sanitary drainage system

Two names are possible: sewage installation, or sanitary drainage system.

This part is divided into several sections. The first is "Introduction" and covers basic definitions. The following section presents characteristics and principles of designing of elements of sanitary drainage systems. These includes fixture drains, stacks, and sewer service line.

In the last section, materials used to construction sewage installations are considered.

# Introduction

Plumbing system – the system of pipe, fittings, devices within a building that include:

- water supply distribution pipes
- fixtures and fixture traps
- soil, waste and vent pipes
- building drain
- building sewer
- stormwater drainage system with its devices, accessories and connections inside and outside the building

# Introduction

Basic plumbing systems:

- potable water supply system,
- **sanitary drainage and vent piping system**,
- stormwater drainage system.

The sanitary drainage system conveys sewage from plumbing fixtures and appliances to a sanitary sewer.

# Sanitary drainage system

A sanitary drainage system is constructed using sanitary drainage pipes and fittings.

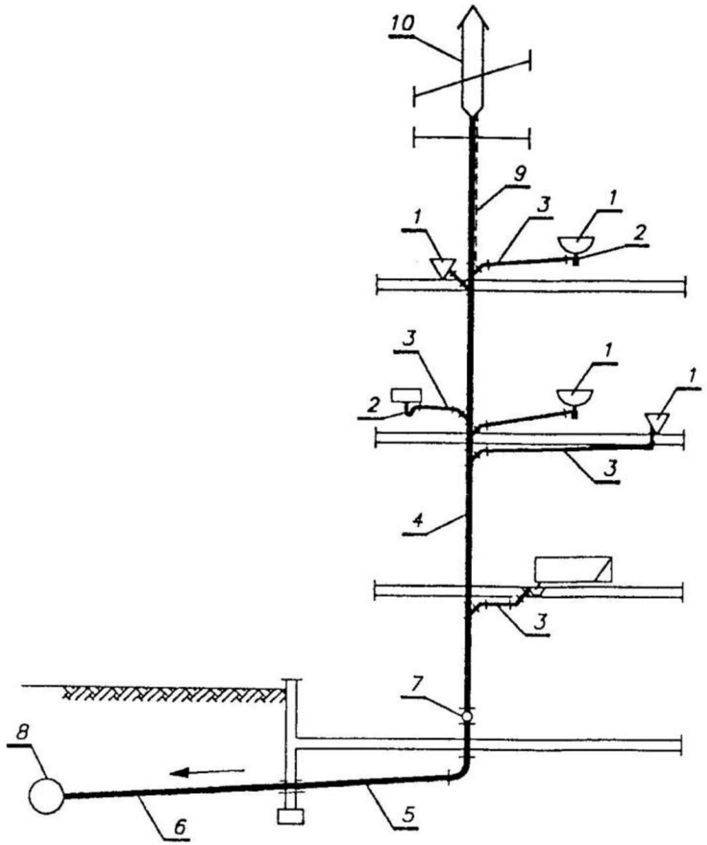
PIPE – a cylindrical tube used for conveying wastewater, waterborne waste, and air from one location to another location

FITTING – a device which is fastened to the ends of pipes to make connections between individual pipes

# Sanitary drainage system

| | | |
|---|---|---|
| WASTE PIPE | – | conveys only liquid waste that is free of fecal matter (lavatory) |
| SOIL PIPE | – | conveys the discharge of water closet or other similar fixtures, containing fecal matter, with or without discharge of other fixtures, to a building drain/building sewer |
| STACK | – | any vertical line (soil, waste, vent pipe) extending through one or more floors |

# Scheme of sewage installation



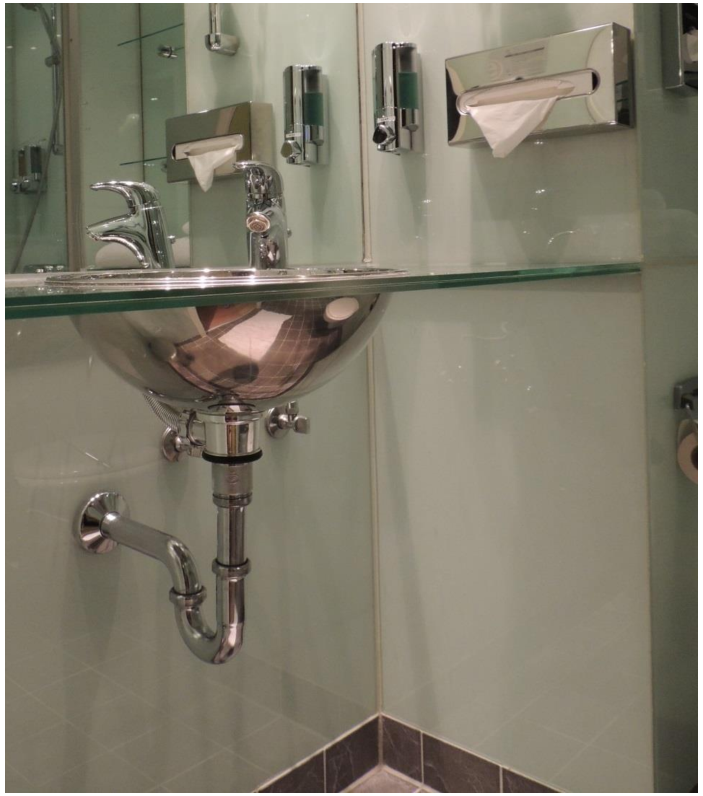

1 – plumbing fixture
2 – trap
3 – branch
4 – soil stack
5 – horizontal drain pipe
6 – sewer service line
7 – stack cleanout
8 – sewer main
9 – stack vent
10 – roof vent

*Source: Jarecka 2000*

# Plumbing traps

Every fixture which is directly connected to the sanitary drainage system must have a liquid-seal trap.
Its construction prevents passage of air/gas through a pipe and at the same time permits the flow of wastewater through a pipe to the sanitary drainage system.

# P-traps



The pictures present the example of a  P-trap for a lavatory in a hotel bathroom.

# Another type of trap

The picture presents another type of trap.

# Trap seal loss

Trap seal loss is caused by:

- siphonage
- back pressure
- evaporation (many weeks to evaporate under normal conditions)
- capillary attraction
- leaks
- wind effect

# Fixture drain and branch

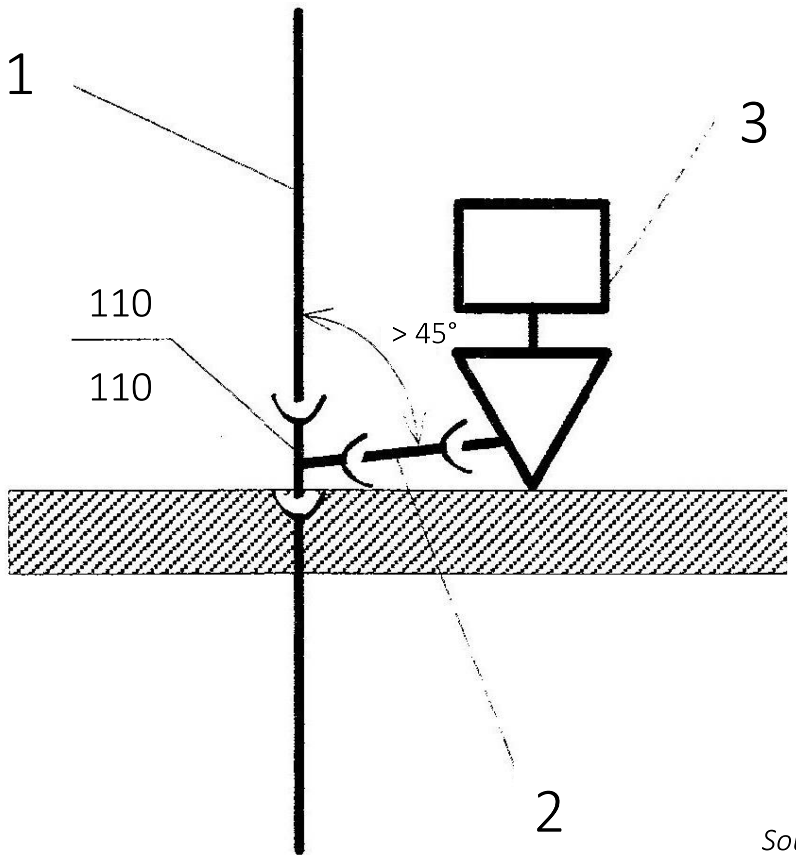
Firstly, wastewater and waterborne waste flows through a fixture trap. The wastewater then enters a **fixture drain.**

FIXTURE DRAIN – drainage pipe that extends from the trap of the fixture to the junction of the next drainage pipe.

When multiple fixture are on the same floor, wastewater flows into a horizontal branch.

HORIZONTAL BRANCH – soil/waste pipes that receive the discharge from fixtures on the same floor and extend horizontally from a stack.

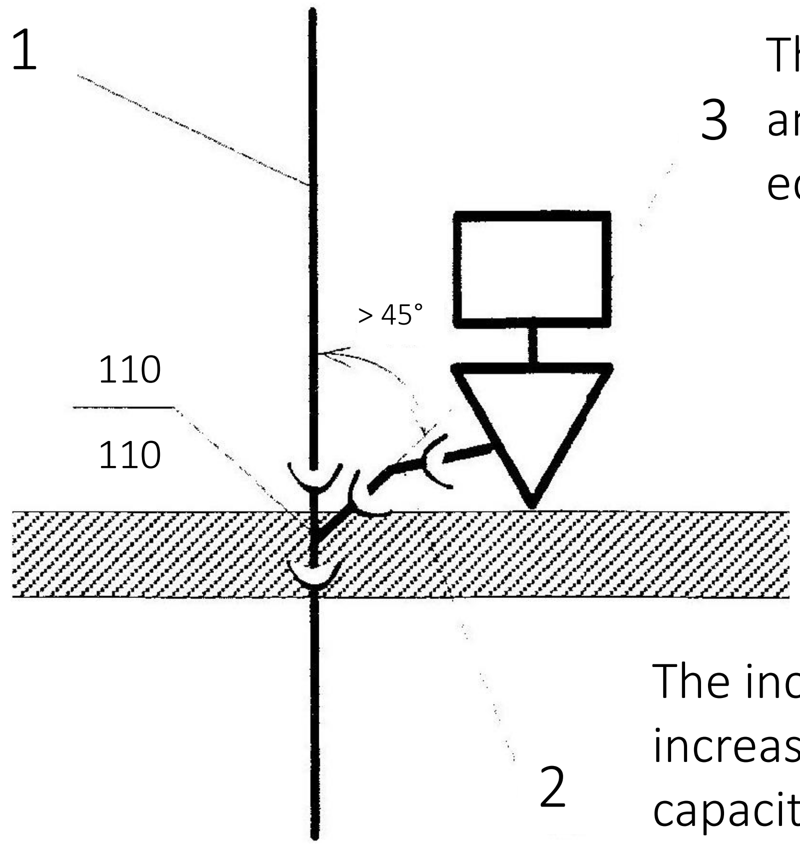
# Angle inlet




The angle between the stack pipe and the branch /fixture drain must be greater than 45 degrees.

*Source: Chudzicki, Sosnowski 2011*

# Inclined inlet




The angle between the stack pipe and the branch/fixture drain is equal to or less than 45 degrees.

The inclined inlet allows increasing the hydraulic capacity of the stack

*Source: Chudzicki, Sosnowski 2011*

# Fixture drain

Types:

- above the ceiling
- in the ceiling
- below the ceiling
- in the installation walls (skeletal)

Depending on the type of way of running the pipe:

- in furrows
- outside the walls

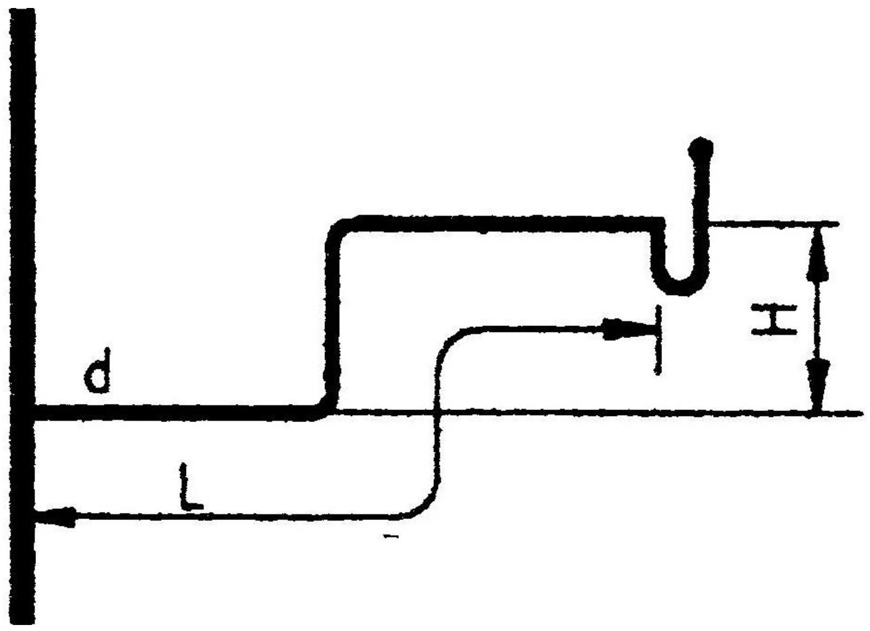
Depending on the number of connected devices:

- single
- collective

# Fixture drain

- Minimal slope – 2%
- The diameter of the fixture drain depends on the type of connected fixture, length and height between the highest outlet from the drainage fitting and the connection to the stack
- Single connections to basins, sinks and bidets with a diameter of 40 mm should not have more than 3 changes in the direction of flow (if they have more than 3, increase the diameter to 50 mm)
- Fixture drain to the toilet bowls should be done separately
- Non-ventilated fixture drain to toilet bowls may not be more than 1 m away from the soil stack
- The fixture drain with the largest diameter (from the toilet bowl) should be connected at the lowest level on a given storey

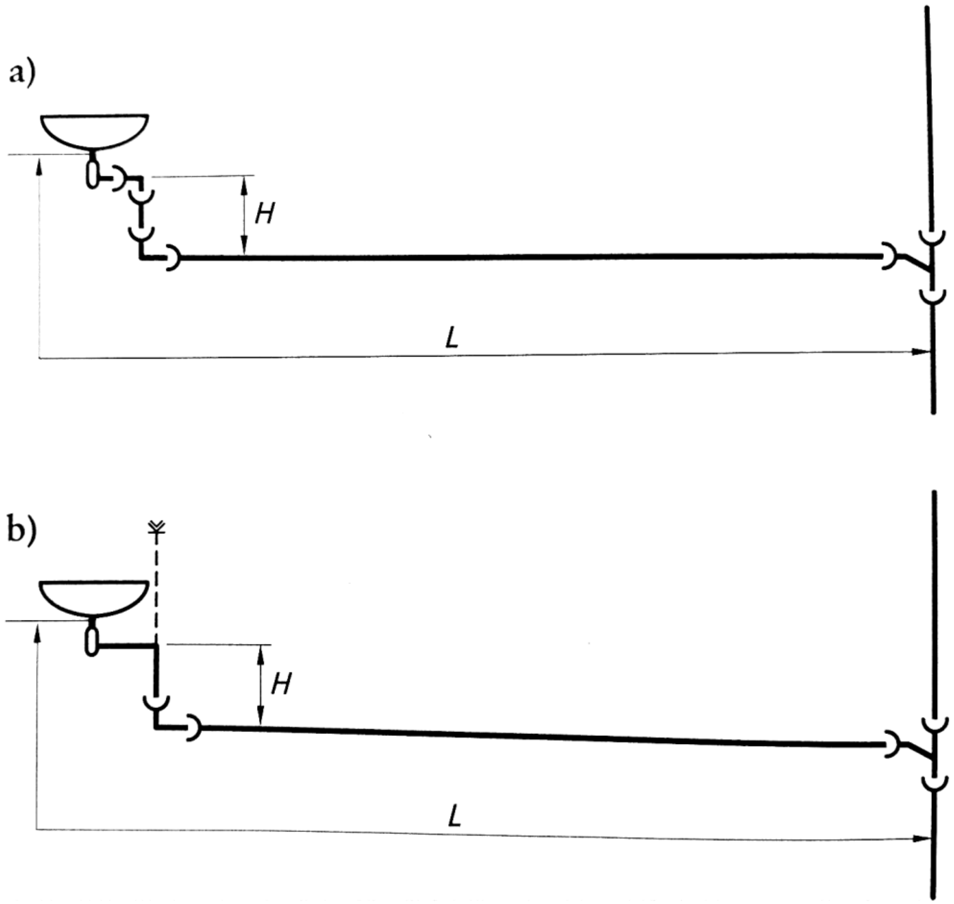
# Fixture drain (according to PN 92/B-01707-02)




Length and height between the highest outlet from the drainage fitting and the connection to the stack.

*Source: Jarecka 2000*

# Fixture drain



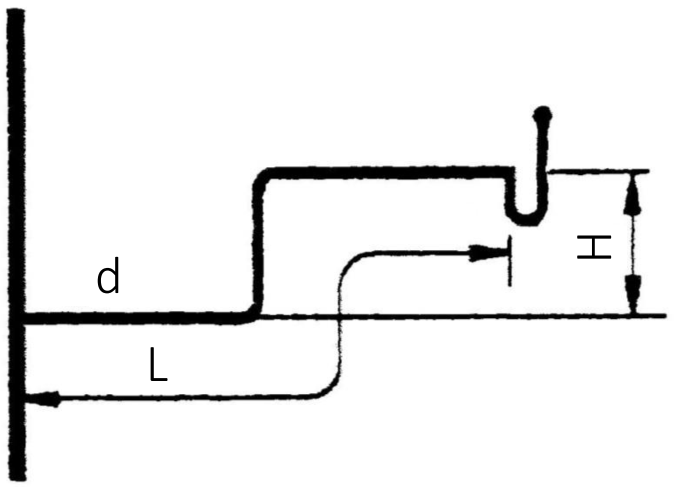

Picture a) presents a nonventilated fixture drain, while picture b) shows a ventilated fixture drain.
The pictures also indicate the determination of drain-pipe length as in the standard PN-EN 12056. The design requirements for fixture drains in the PN EN 12056 standard include, among others, maximum length, maximum height differences, minimum slope and maximum number of arches with an angle of 90 degrees.

*Source: Chudzicki, Sosnowski 2011*

# Fixture drain (according to PN 92/B-01707-02)

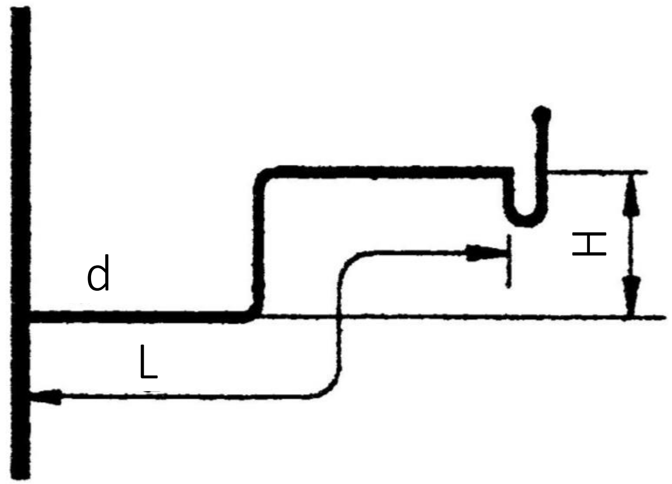
non-ventilated

L ≤ 3 m and H < 1 m




d = 0.04 or 0.05 m

L ≤ 5 m and H < 1 m

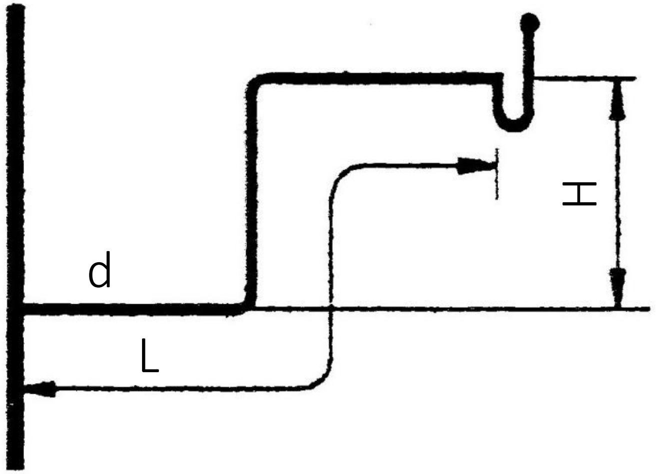



d = 0.07

*Source: Jarecka 2000*

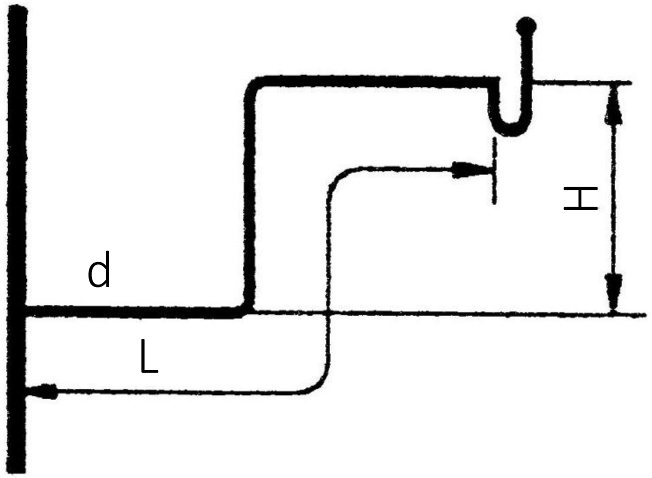
# Fixture drain (according to PN 92/B-01707-02)

L > 3 m or H = 1÷3 m




d = 0.04÷0.05 m
d = 0.05÷0.07 m

L > 5 m or H = 1÷3 m



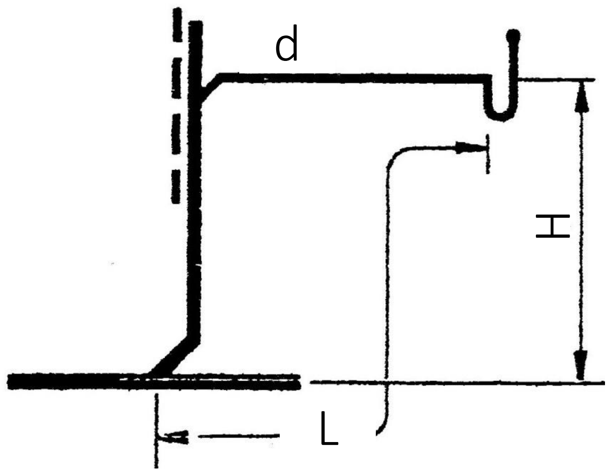

d = 0.07÷0.10 m

*Source: Jarecka 2000*

# Fixture drain (according to PN 92/B-01707-02)

ventilated

H > 3 m or H > 3 m (for d = 0.04 and 0.05 m)
and L > 5 m (for d = 0.07 m)



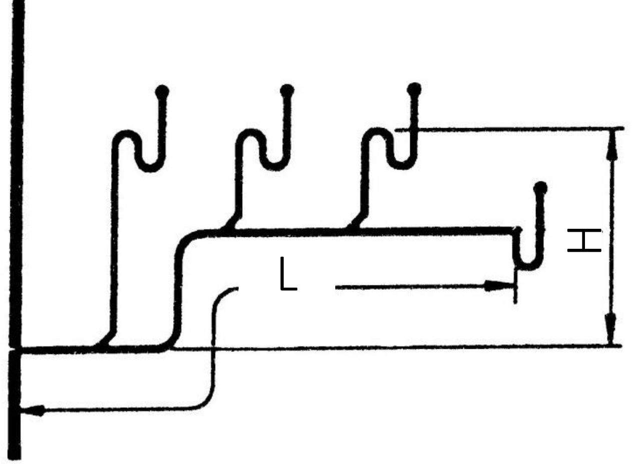

ventilation
for d = 0.04÷0.10 m

*Source: Jarecka 2000*

# Fixture drain and horizontal branch (according to PN 92/B-01707-02)

non-ventilated

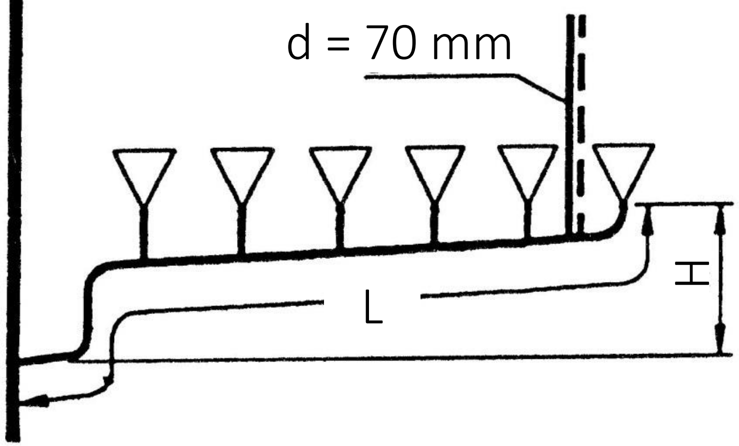
L ≤ 6 m and H = 1÷3 m




d = 50 → 70 mm

ventilated

H > 1 m and ventilation




d = 70 → 100 mm

*Source: Jarecka 2000*

# Stack

Any vertical line of soil/waste/vent pipe extending through one or more stories.

- Waste stack
- Soil stack (soil pipe)
- Vent stack (vertical pipe that provides circulation of air to and from drainage system)

but

Stack vent is an extension of the waste/soil stack that runs up through the roof to the exterior (above the highest horizontal drain connected to the stack).

# Stack

- The minimum diameter of the stack is 70 (75) mm
- The diameter of the stack cannot be smaller than the diameter of the largest connected fixture drain
- Maximum permissible stack deviation is 10 mm
- The stack should be placed centrally in relation to the sanitary utensils, close to the toilet bowls
- Stacks should be run in rooms with a temperature higher than 0°C
- Stacks installed in rooms intended for permanent residence should be acoustically secured

# Stack

- Horizontal displacement should be achieved using arcs and offsets
- The lowest branch should be at a minimum height of 50–75 cm above the building drain
- For stacks with heights greater than 10 m in the last 2 m section, do not connect fixture drain/branch to the stack directly

# Stack

Pipe routing:

- outside the walls
- furrows and installation shafts

Furrows:

- free access to the installation
- the possibility of pipe movement related to thermal elongation
- air insulation around the stack
- it is not allowed to attach pipe permanently to wall
- furrow dimensions are larger by at least 5 cm from the dimensions of the stack pipe socket

# Stacks in multistorey buildings

Traditional connection

New alternative

The pictures show differencies between traditional connections and Geberit’s new line of alternative fittings – ‘SOVENT’.

*Source: geberit.pl/produkty/systemy-rurociagow-kanalizacyjnych/ksztaltka-geberit-sovent/*

# Stacks in multistorey buildings

Traditional connection

- Connection of wastewater from the horizontal branch from the storey and soil stack
- Without additional ventilation, rapid pressure changes cause the sewage to be sucked in from the horizontal branches and stacks
- Necessity to install the vent stack

New alternative

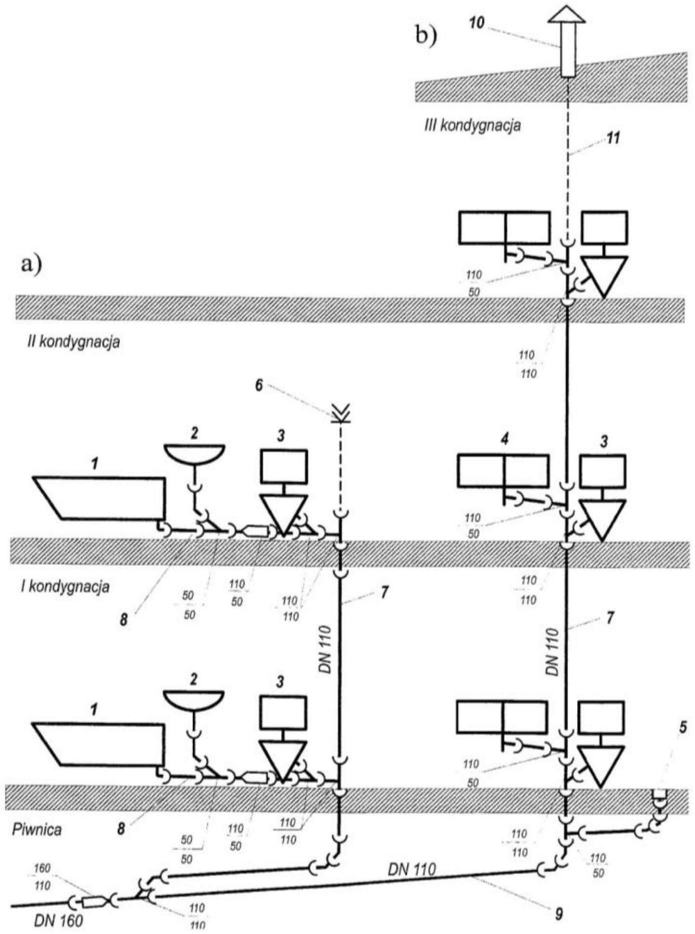
- Separation of wastewater from the soil stack and horizontal branches from the storey
- Pressure compensation takes place inside the soil stack
- Smaller dimensions of the soil stack needed; no need for additional vent stack
- It lowers costs and takes up less space

# Sovent

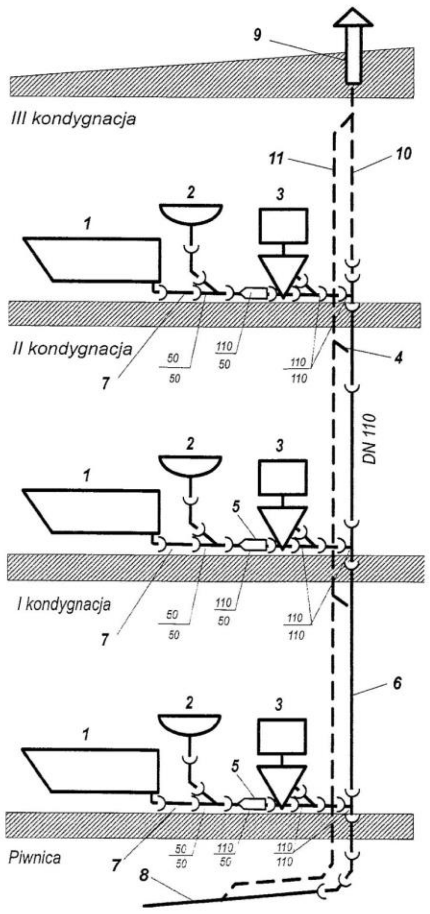
The photographs are of Geberit's  SOVENT special fittings.

# Vent stack vs. Stack vent

Main ventilation




Bypass ventilation



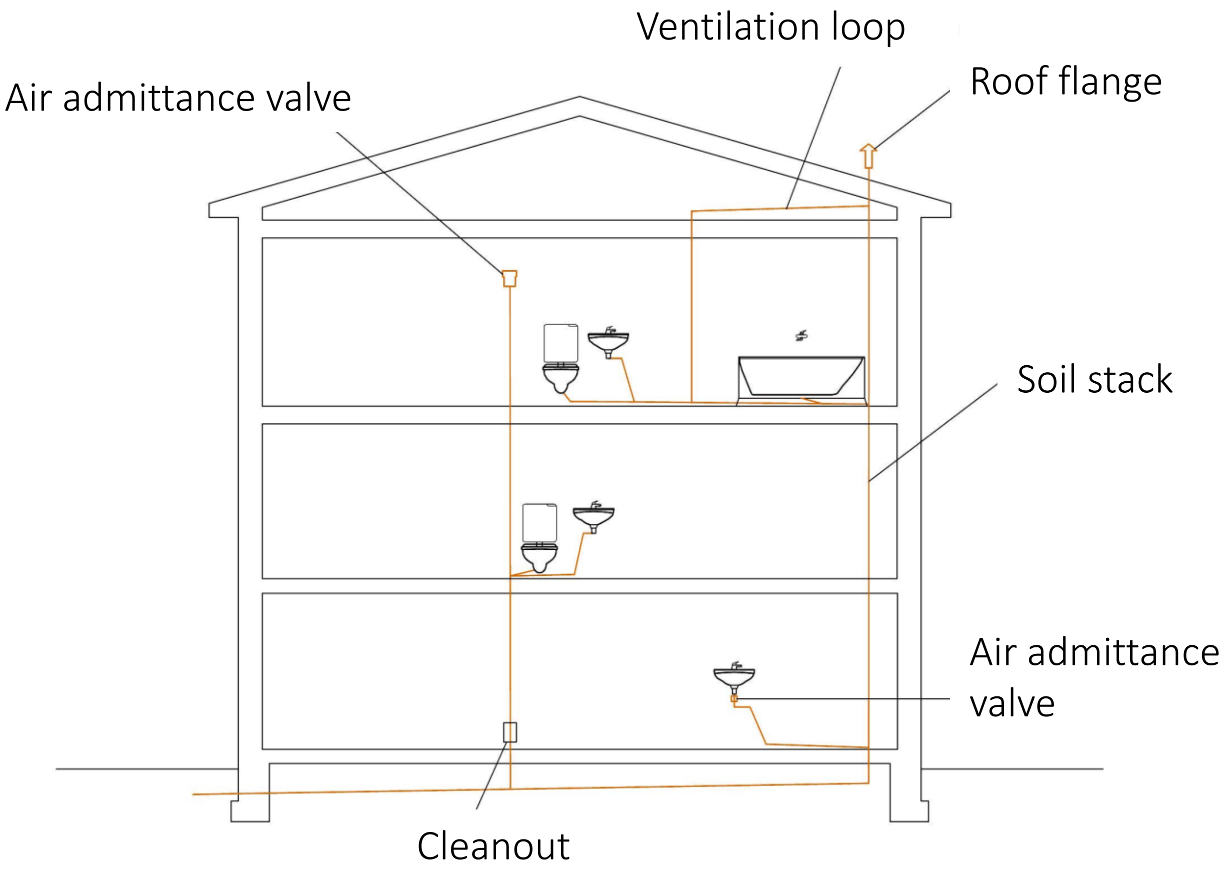

*Source: Chudzicki, Sosnowski 2011*

# Vent pipe

**Vent pipe** – a pipe to ventilate the drainage system of a building and prevent trap siphonage and back pressure.

Roof jacket roof vent
Roof flange

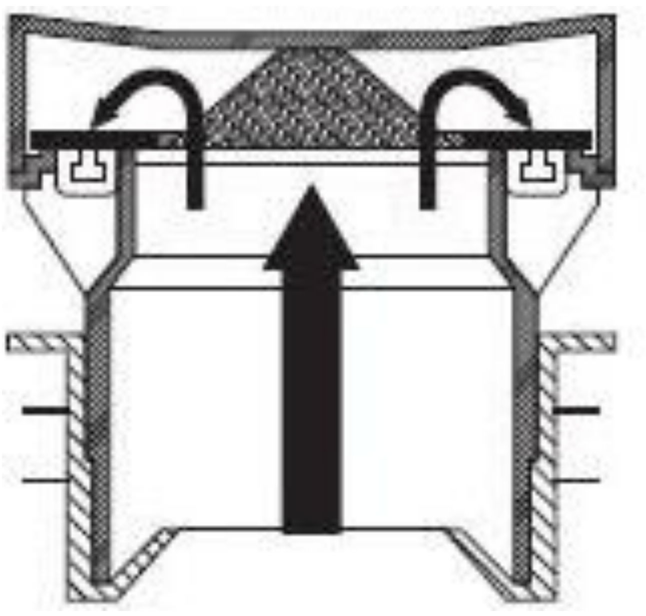
It is a jacket/flange installed on the roof terminal of a vent stack or stack vent to seal the opening so that rainwater cannot enter the building around the vent pipe.



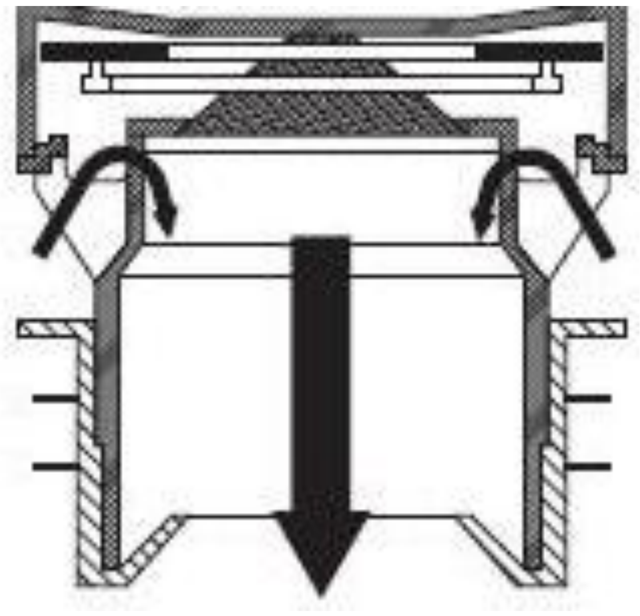

*Source: mpwik-zywiec.pl/uslugi/ochrona-srodowiska/siec-kanalizacyjna/wyposazenie-techniczne-budynkow.html*

# Admittance valve

Close



Open



*Source: instsani.pl/758/rury-wywiewne-i-zawory-napowietrzajace*

# Cleanout

**Cleanout** – a fitting with a removable cap (or plug) installed in a sanitary drainage pipe that allows access to the pipe for removing stoppages from the pipe and for cleaning the interior of the pipe. It is located at the base of waste/soil stacks or near the front wall of a building.

- Stack cleanouts
- Front main cleanout

# Stack cleanout

The photographs show the cleanout located at the base of a soil stack in a building.

# Horizontal drain building drain

It is the part of the lowest piping of a drainage system that receives the discharge from soil/waste pipes inside the walls of building and conveys it to the building sewer.

# Sewer service line building sewer

It is the part of drainage system that extends from the end of building drain and conveys its discharge to the public sewer or other point of disposal.

It is the part of drainage system that extends from the end of building drain and conveys its discharge to the public sewer or other point of disposal.

**Slope**: minimum 2% in the direction of the sanitary sewer

**Material:** plastic, other

# Sewer service line building sewer

- the minimum diameter of the sewer service line should be 0.15 m (160 mm)
- changes in directions and slopes in the sewer service line pipes are carried out in inspection chambers
- at the intersection of the pipe of the sewer service line with the water service pipe at a distance of less than 0,6 m, the sewage pipe should be in a protective pipe
- when running the pipe of the sewer service line under streets and roads with heavy traffic, the minimum height of the pipe cover is 1.4 m
- the sewer service line should be perpendicular to the wall of the building and to the external sewage system
- drainage of sewage from the building should be done through one sewer service line

# Sewer service line building sewer

Minimum distances from parallel pipes of other installations are:

- 1.5 m from water and gas lines
- 0.8 m from energetic cables
- 0.5 m from telecommunications cables.

Sewer service line located outside the building should be run at a depth ensuring that the pipe is covered with a layer of ground with a height of 0.2 m greater than the depth of freezing of the ground for a given zone.

# Sanitary sewer sewer main

- as sewage exits the building sewer, it enters the sanitary sewer
- it is a sewer that carries sewage
- it does not convey rainwater, surface water, groundwater
- European Norm EN 752

# Materials: stoneware

- produced from clay with the addition of chamotte
- after firing, the inner and outer walls of the pipes are often glazed
- uses a Spigot and Socket type joint

Individual pipes are most often combined using the Spigot and Socket joint (barrel and socket).
The seal is formed between the Socket (or female end) and the outside of the Spigot (or male end).

# Materials: stoneware

# Materials: stoneware

ADVANTAGES:
- durability
- resistance to aggressive substances
- tightness
- high strength
- minimal wall roughness

DISADVANTAGES:
- fragility

# Materials: plastic

PLASTIC – a synthetic material manufactured from petroleum – based products and chemicals such as oil, natural gas and coal.

MANUFACTURING PROCESS

RAW MATERIALS → RESINS

thermosetting

thermoplastic

(can be heated and reformed repeatedly with little or no degradation in physical charactristics)

# Materials: plastic

- ABS (Acrylonitrile – Butadiene – Styrene)
- PVC (Polyvinyl Chloride)
- PP (Polypropylene)
- PE (Polyethylene) – HDPE

# Materials: plastic

ADVANTAGES:

- lightweight
- inexpensive
- easily joined
- resistant to most household chemicals, acids and other corrosive liquids
- smooth interior walls
- low thermal conductivity
- they do not decay and can resist bacteria growth that could cause offensive odors
- good flexibility (this allows long pipe runs with a minimum number of joints)
- does not conduct electricity
- not subject to galvanic or electrolytic corrosion

# Materials: plastic

DISADVANTAGES:

- have very high rate of expansion and contraction when heated and cooled
- have low heat resistance
- give off harmful vapors when burned
- required hangers and support spaced at closer intervals (than metallic pipe)
- can be stored outdoor only if they are properly covered and not exposed to sunlight or extreme weather conditions

# Materials: Cast Iron

- gray cast iron pipe
- ductile iron pipe
- no-hub
- bell – and – spigot

# Materials: Cast Iron

**ADVANTAGES:**

- leakproof
- nonabsorbent
- corrosion – resistant
- easilily cut and joined
- provides a quiet plumbing system (cast iron does not transmit the sound of water draining through the pipe)

**DISADVANTAGES:**

- heavy
- low tensile strength
- may crack or break if not handled properly

# Materials: Steel

ADVANTAGES:

- relatively inexpensive
- strong
- not easily damaged

DISADVANTAGES:

- rugged
- installation cost
- weight

# Calculation methods

The calculation methods of sanitary drainage system:

- according to PN-EN 12056:2002

Gravity drainage systems inside buildings Part 2: Sanitary pipework, layout and calculation

- according to the PN-92/B-01707
- other

# Hydraulic calculations of sanitary drainage system

The method is applicable only to gravity sanitary drainage systems.

Sewage systems for drainage of wastewater from service and industrial facilities should be calculated individually.

All flow rates given in the standard (in the basic data section) are specified for the minimum internal diameters. These are listed in the table.

*According to PN EN 12056: 2002*

# Nominal diameters and the corresponding minimum internal diameters

| The nominal diameter | The minimum internal diameter |
| --- | --- |
| DN | di min [mm] |
| 30 | 26 |
| 40 | 34 |
| 50 | 44 |
| 56 | 49 |
| 60 | 56 |
| 70 | 68 |
| 80 | 75 |
| 90 | 79 |
| 100 | 96 |

… up to DN 300

*According to PN EN 12056: 2002*

# Hydraulic calculations of sanitary drainage system according

The European standard PN EN 12056 distinguishes four types of sewage systems depending on:

- designed filling of fixture drain connections
- type of sewage discharged (grey sewage and black sewage)

In Poland and in the majority of European countries, the **I system** is most commonly used.

| Type of system | Characteristic |
|---|---|
| I | fixture drain connections to soil/waste stack at **50%** depth of flow |
| II | fixture drain connections to soil/waste stack at **70%** depth of flow (fixture drain with smaller diameter) |
| III | fixture drain filled to **100%** (each fixture drain connected separately to the soil/waste stack) |
| IV | type I, II, III but separated gray and black sewage (DUAL INSTALLATION) |

*According to PN EN 12056: 2002*

# Ventilation

Air flow in the fixture drains and stack pipes is ensured by applying appropriate ventilation solutions for the sanitary drainage system components.

The stack pipe:

- with main ventilation
- with bypass ventilation

The fixture drain:

- non-ventilated
- ventilated

Vent Stack vs. Stack Vent – see p. 383

# Hydraulic calculations of sanitary drainage system according to PN-EN 12056:2002

The discharge units  depend on the type of plumbing fixtures and the type of system.
For each type of system and sanitary facility, discharge units are included in the table.
The discharges from the plumbing fixtures not listed in the table should be defined individually.

| Plumbing fixture | Type of system | | |
| --- | --- | --- | --- |
| | I<br>DU l/s | II<br>DU l/s | III<br>DU l/s |
| Washbasin, bidet | 0.5 | 0.3 | 0.3 |
| Shower without a stopper | 0.6 | 0.4 | 0.4 |
| Shower with a stopper | 0.8 | 0.5 | 1.3 |
| Urinal with flushing cistern | 0.8 | 0.5 | 0.4 |
| Urinal with flushing valve | 0.5 | 0.3 | – |
| Plate urinal | 0.2* | 0.2* | 0.2* |
| Bathtub | 0.8 | 0.6 | 1.3 |
| Sink | 0.8 | 0.6 | 1.3 |
| Dishwasher (domestic) | 0.8 | 0.6 | 0.2 |
| Washing machine up to 5 kg | 0.8 | 0.6 | 0.6 |

*According to PN-EN 12056: 2002. The standard also includes requirements for IV systems.*

| Plumbing fixture | Type of system | | |
| --- | --- | --- | --- |
| | I<br>DU l/s | II<br>DU l/s | III<br>DU l/s |
| Washing machine up to 12 kg | 1.5 | 1.2 | 1.2 |
| Flushing toilet with flushing cistern 4 l | ** | 1.8 | ** |
| Flushing toilet with flushing cistern 6 l | 2.0 | 1.8 | 1.2–1.7*** |
| Flushing toilet with flushing cistern 7.5 l | 2.0 | 1.8 | 1.4–1.8*** |
| Flushing toilet with flushing cistern 9 l | 2.5 | 2.0 | 1.6–2.0*** |

*According to PN-EN 12056: 2002. The standard also includes requirements for IV systems.*

| Plumbing fixture | Type of system | | |
|---|---|---|---|
| | I<br>DU l/s | II<br>DU l/s | III<br>DU l/s |
| Floor drains DN 50 | 0.8 | 0.9 | - |
| Floor drains DN 70 | 1.5 | 0.9 | - |
| Floor drains DN 100 | 2.0 | 1.2 | - |
| * – per person | | | |
| ** – not recommended | | | |
| *** – depending on the type (use only tanks with siphons) | | | |
| - – not used or no data available | | | |

*According to PN-EN 12056: 2002. The standard also includes requirements for IV systems.*

# Hydraulic capacity of fixture drain (without ventilation) and nominal diameter

| Qmax | System I | System II |
|---|---|---|
| l/s | DN [mm] | DN [mm] |
| 0.4 | not recommended | 30 |
| 0.5 | 40 | 40 |
| 0.8 | 50 | not recommended |
| 1 | 60 | 50 |
| 1.5 | 70 | 60 |
| 2 | 80* | 70* |
| 2.25 | 90** | 80*** |
| 2.5 | 100 | 90 |

* without flushing toilets
** not more than two flushing toilets and total change of direction not more than 90 degrees
*** not more than one flushing toilet

*According to PN-EN 12056: 2002.*

# Typical diameters of fixture drains

- washbasin: 40 mm
- sink, shower, washing machine: 50 mm
- flushing toilet: 100 mm

# Fixture drain

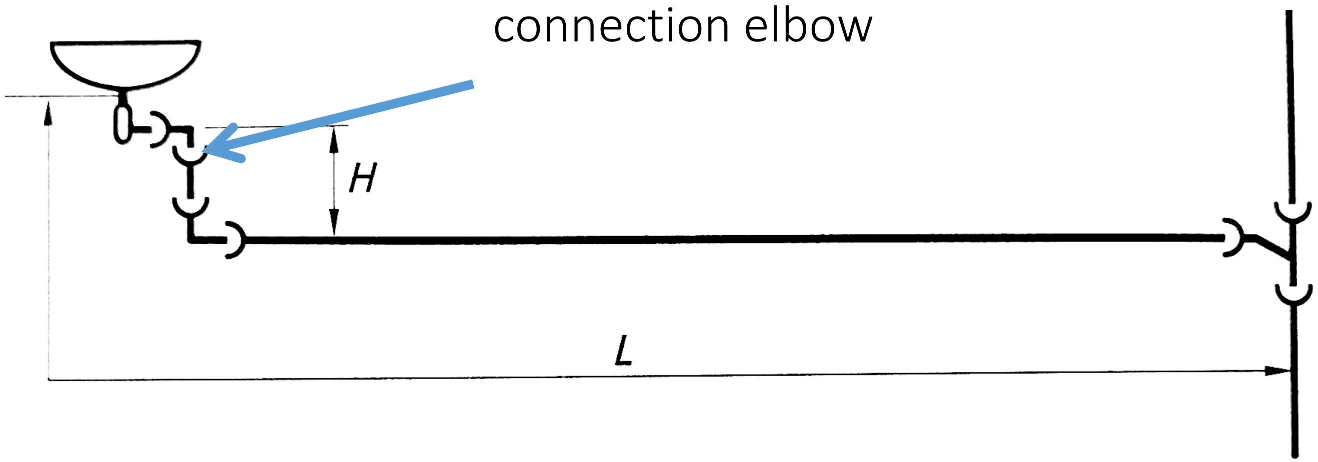
Types of fixture drain depending on the number of connected plumbing fixtures:

- collective
- single

The photograph at the left presents a collective fixture drain (for shower and for washbasin). The photograph at the right presents a single fixture drain (for water closet).

# Fixture drain – restrictions

The diameter of the fixture drain depends on the type of connected fixture, length and height between the highest outlet from the drainage fitting and the connection to the stack.




Length and height between the highest outlet from the drainage fitting and the connection to the stack.

*Source: Chudzicki, Sosnowski 2011*

# Non – ventilated fixture drains – restrictions

- minimal slope – 1% (for system I and IV) and 1.5% (for system II)

(BUT:
according to technical literature, the recommended minimum slope of fixture drain is 2%)

- maximum length of fixture drain (L):
  - ✓ 4 m (for system I)
  - ✓ 10 m (for system II and IV)

*According to PN-EN 12056: 2002.*

# Non – ventilated fixture drains – restrictions

- maximum height difference (H):
  - ✓ 1 m (for system I and IV)
  - ✓ 3 m for DN = 70 mm or 6 m for DN > 70 mm (for system II)
- maximum number of arches with an angle of 90 degrees:
  - ✓ 3 (without connecting elbow) – (for system I and IV)
  - ✓ 1 (without connecting elbow) – for system II)
- maximum number of arches with an angle of 90 degrees:
- 3 (without connecting elbow) – for system I

If these limits (restrictions) cannot be maintained, larger diameters, air admittance valves or ventilated fixture drains should be used.

*According to PN-EN 12056: 2002.*

# Table. Sizing of fixture drains

| Symbol | Plumbing fixture | Discharge unit [l/s] | Diameter of fixture drain [mm] |
|---|---|---|---|
| H | | | |
| G | | | |
| F | | | |
| E | | | |
| D | | | |
| C | | | |
| B | | | |
| A | | | |

# According to the method PN-EN 12056:2002
## Wastewater flow rate

Method from the Polish Norm and European Norm.

$$Q_{WW} = K \cdot \sqrt{DU}, \quad \mathrm{dm^3/s}$$

where:

$Q_{WW}$ – wastewater flow rate, $dm^3/s$,
$K$ – frequency coefficient,
$\sqrt{DU}$ – the sum of discharge unit

# Typical K frequency coefficient

| Type of building | K |
|---|---|
| Use discontinuous e.g. in an apartment, office, guesthouse | 0.5 |
| Periodic use e.g. in a hospital, school, restaurant, hotel | 0.7 |
| Using collective e.g. public toilets and showers | 1.0 |
| Special use, e.g. laboratories | 1.2 |

*According to PN-EN 12056: 2002.*

# According to the method PN-EN 12056:2002

## Total wastewater flow rate

Wastewater could come from:

- plumbing fixtures ($Q_{ww}$)
- devices with continuous flow ($Q_c$)
- the pumping station ($Q_p$).

# According to the method PN-EN 12056:2002

## Total wastewater flow rate

Method from the Polish Norm and European Norm.

$$Q_{tot} = Q_{ww} + Q_c + Q_p$$

where:

- $Q_{tot}$ – total flow rate, $dm^3/s$,
- $Q_{WW}$ – wastewater flow rate, $dm^3/s$
- $Q_c$ – continuous wastewater flow rate, $dm^3/s$
- $Q_p$ – flow rate of pumped wastewater, $dm^3/s$

# Designing principle

The pipe capacity should not be less than:

- Qww or Qtot value
- value of the outflow from the plumbing fixture with the largest discharge unit

For simplicity, the standard contains table (Annex B) with calculated $Q_{ww}$ values for different frequency coefficients K and different sums of discharge units.

*According to PN-EN 12056: 2002.*

# Stack pipe

- The minimum diameter of the stack is 60 mm (according to the standard PN EN 12056)

BUT:

- according to technical literature, the minimum diameter of the stack is 70 (75) mm

Types:

Angle inlet (see: p. 366) Inclined inlet (see: p. 367)

- By using an inclined inlet, it is possible to increase the hydraulic capacity of the stack without changing its diameter.

The inclined inlet allows increasing the hydraulic capacity of the stack. This is a very important feature – especially for multistorey buildings.

Horizontal drain/building drain – see p. 389.

# Hydraulic capacity of soil/waste stack and limits – main ventilation

| STACK AND VENTING PIPE | SYSTEM I, II $Q_{max}$ [l/s] | |
|---|---|---|
| DN [mm] | ANGLE INLET | INCLINED INLET |
| 60 | 0.5 | 0.7 |
| 70 | 1.5 | 2 |
| 80* | 2 | 2.6 |
| 90 | 2.7 | 3.5 |
| 100** | 4 | 5.2 |
| 125 | 5.8 | 7.6 |
| 150 | 9.5 | 12.4 |
| 200 | 16 | 21 |

*According to PN-EN 12056: 2002.*

# Hydraulic capacity of soil/waste stack and limits – bypass ventilation

| STACK AND VENTING PIPE | SYSTEM I, II $Q_{max}$ [l/s] | |
|---|---|---|
| DN [mm] | ANGLE INLET | INCLINED INLET |
| 60 | 0.7 | 0.9 |
| 70 | 2 | 2.6 |
| 80* | 2.6 | 3.4 |
| 90 | 3.5 | 46 |
| 100** | 5.2 | 7.3 |
| 125 | 7.6 | 10 |
| 150 | 12.4 | 18.3 |
| 200 | 21 | 27.3 |

*According to PN-EN 12056: 2002.*

# Limits: minimal diamater of stacks

*minimal diameter, if flushing toilet in system III
** minimal diameter, if flushing toilet in system I, II, IV
The same limits for main ventilation and bypass ventilation.

*According to PN-EN 12056: 2002.*

# Sizing of stacks

| Stack | Symbols of plumbing fixtures that have an outlet in the stack | Sum of DU | K | Flow rate | Diameter of the stack |
|---|---|---|---|---|---|
| **SOIL STACK:** | | | | | |
| **WASTE TACK:** | | | | | |

# Hydraulic capacity of horizontal drains

- The hydraulic capacity of horizontal drains should be calculated using properly defined patterns, tables or nomograms.
- In case of doubt, the Colebrook – White (Prandtl – Colebrook) equation should be used.
- For simplicity, the standard includes a table (Annex B) with calculated hydraulic capacities based on the Colebrook White equation.

# Hydraulic capacity of horizontal drains

| Slope [cm/m] | DN 100 | | DN 124 | | DN 150 | | DN 200 | | DN 225 | | DN 250 | | DN 300 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] |
| 0.5 | 1.8 | 0.5 | 2.8 | 0.5 | 5.4 | 0.6 | 10.0 | 0.8 | 15.9 | 0.8 | 18.9 | 0.9 | 34.1 | 1.0 |
| 1.0 | 2.5 | 0.7 | 4.1 | 0.8 | 7.7 | 0.9 | 14.2 | 1.1 | 22.5 | 1.2 | 26.9 | 1.2 | 48.3 | 1.4 |
| 1.5 | 3.1 | 0.8 | 5.0 | 1.0 | 9.4 | 1.1 | 17.4 | 1.3 | 27.6 | 1.5 | 32.9 | 1.5 | 59.2 | 1.8 |
| 2.0 | 3.5 | 1.0 | 5.7 | 1.1 | 10.9 | 1.3 | 20.1 | 1.5 | 31.9 | 1.7 | 38.1 | 1.8 | 68.4 | 2.0 |
| 2.5 | 4.0 | 1.1 | 6.4 | 1.2 | 12.2 | 1.5 | 22.5 | 1.7 | 35.7 | 1.9 | 42.6 | 2.0 | 76.6 | 2.3 |
| 3.0 | 4.4 | 1.2 | 7.1 | 1.4 | 13.3 | 1.6 | 24.7 | 1.9 | 38.9 | 2.1 | 46.7 | 2.2 | 83.9 | 2.5 |
| 3.5 | 4.7 | 1.3 | 7.6 | 1.5 | 14.4 | 1.7 | 26.6 | 2.0 | 42.3 | 2.2 | 50.4 | 2.3 | 90.7 | 2.7 |
| 4.0 | 5.0 | 1.4 | 8.2 | 1.6 | 15.4 | 1.8 | 28.5 | 2.1 | 45.2 | 2.4 | 53.9 | 2.5 | 96.9 | 2.9 |
| 4.5 | 5.3 | 1.5 | 8.7 | 1.7 | 16.3 | 2.0 | 30.2 | 2.3 | 48.0 | 2.5 | 57.2 | 2.7 | 102.8 | 3.1 |
| 5.0 | 5.6 | 1.6 | 9.1 | 1.8 | 17.2 | 2.1 | 31.9 | 2.4 | 50.6 | 2.7 | 60.3 | 2.8 | 108.4 | 3.2 |

*According to PN-EN 12056: 2002. The filling depth of the pipes is 50%.*
*Source: Chudzicki, Sosnowski 2011*

# Designing of air admittance valves
## $Q_a$ – minimal air flow rate

- Air admittance valve for fixture drain:

| System | $Q_a$ [l/s] |
|---|---|
| I | $Q_{tot}$ |
| II | $2Q_{tot}$ |
| III | $2Q_{tot}$ |
| IV | $Q_{tot}$ |

- Air admittance valve for the stacks:

$$Q_a \geq 8Q_{tot}$$

*According to PN-EN 12056: 2002.*

# Curio


The washbasin for physicians (surgeons) in the newest hospital in Kraków (before start-up).

# Part 10

# *Substainable plumbing*

*Joanna Bąk*

# OUTLINE OF THIS PART:

- Introduction
- Water reclamation and recycling:
  - ✓ harvested rainwater
  - ✓ greywater
  - ✓ blackwater
  - ✓ reclaimed water

- Low – flow plumbing fixtures and appliances
- Systems for the evaluation of fittings and sanitary devices
- Green building rating systems:
  - ✓ breeam
  - ✓ leed
  - ✓ other

# Introduction

- Why is water so important?
- How much and for what purpose do we need water every day?
- What plumbing fixtures or appliances consume the most amount of water per day?

Water resources in the world are limited.  Natural resources are limited. Water is essential for life.

# Sustainable development goals

**Goal 6**: Ensure availability and sustainable management of water and sanitation for all


**Goal 12**: Ensure sustainable consumption and production patterns


*Source: un.org*

# Sustainable plumbing

- practices
- plumbing fixtures and appliances

It is an effort to use water more EFFICIENTLY (REDUCE WATER CONSUMPTION) and REDUCE ENERGY CONSUMPTION.

TWO WAYS for plumbing fixtures:

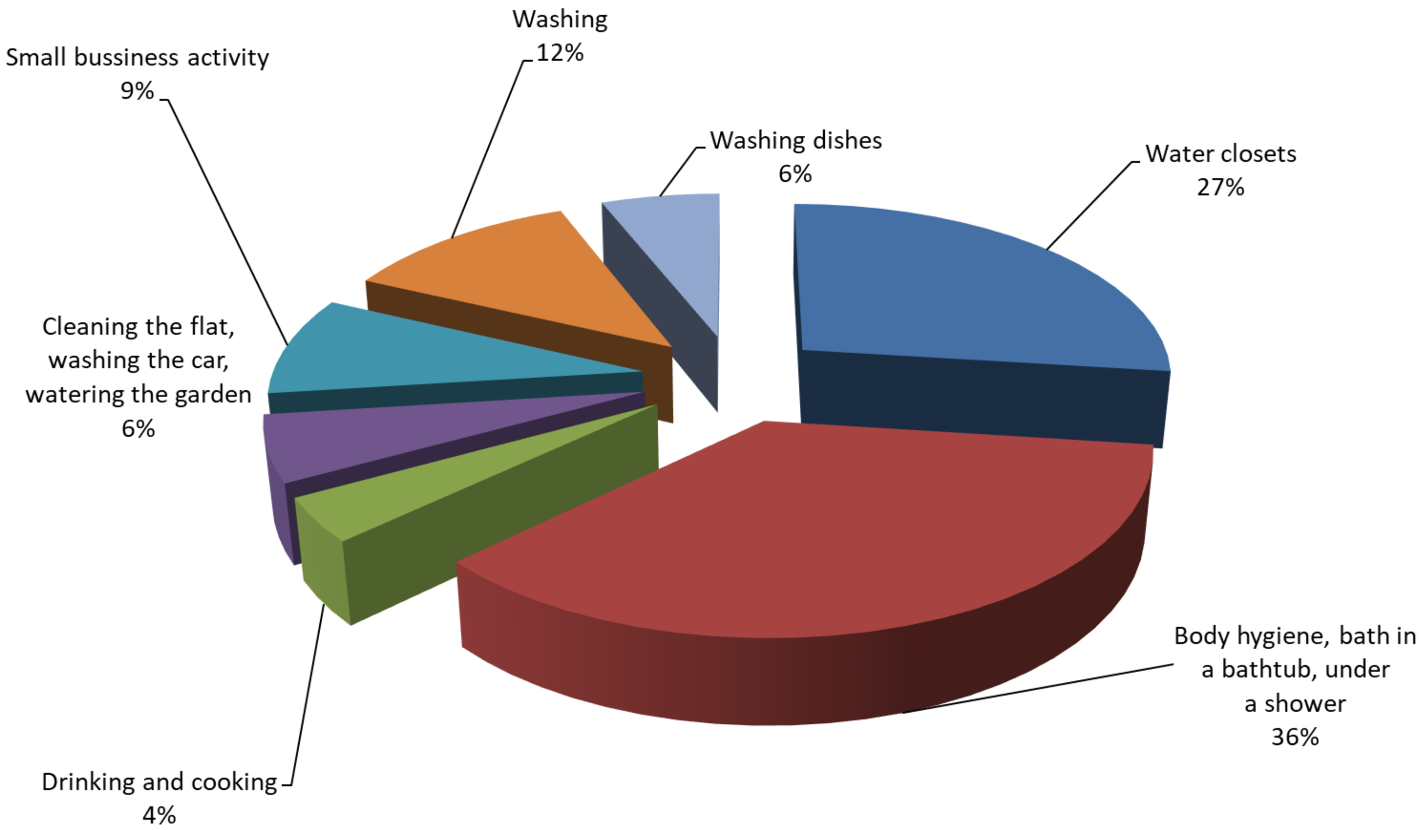
- can be incorporated into existing facilities
  - ✓ modification of existing plumbing fixtures
  - ✓ replacing plumbing fixtures
- must be included in the initial construcion/reconstruction of plumbing installations

# Sustainable plumbing

- replacing older, less efficient fixtures with high efficiency fixtures
- regular inspection and removal of leaks
- drought resistant landscaping
- drought resistant lawn coverings

*Every cubic meter of reclaimed water is one cubic meter less of potable water that needs to be supplied to the building, and one less cubic meter that must be treated at the water treatment plant.*

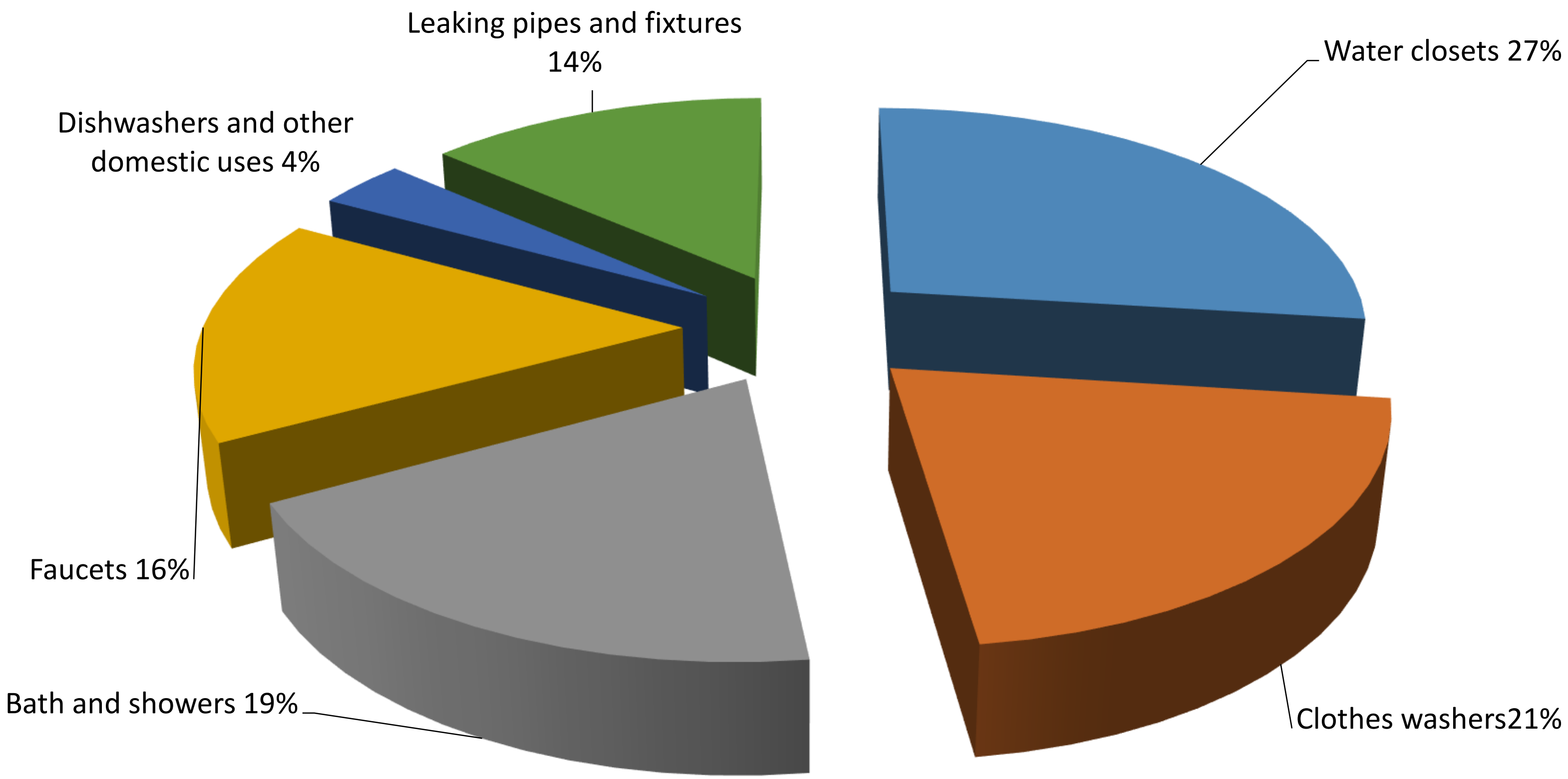
# Unit water demand (according to german guidelines)




The graph shows the structure of water consumption based on German guidelines.

*Source: Chudzicki, Sosnowski 2011*

# Daily indoor water use in the united states




The graph presents daily indoor water use for a typical American.
The amount of 70 gallons/day means 266 litres/day.

*Source: Ripka 2012*

The structure of water consumption (water intended for living and economic needs) according to Polish technical literature – see p. 173.

# Questions about water

What plumbing fixtures or appliances consume the most amount of water per day?

- water closet
- bathtub/shower
- washing machine

# Water reclamation and recycling

Water reclamation – processing of wastewater or rainwater that was intended to go down a **sanitary** or **storm sewer**

**The results of water reclamation include:**

- Harvested rainwater
- Graywater (greywater)
- Blackwater
- Reclaimed water

Each type has certain limitations on its final use.

# Rainwater harvesting


Rainwater harvesting – the process of collecting water from roofs or other exterior sealed surface or paved or vegetated ground for reuse.

- existed prior to written history

Used for:

- ✓ irrigation of landscaping
- ✓ flushing toilets
- ✓ bathing [?]
- ✓ washing clothes [?]
- ✓ to supplement the water in cooling tower applications

- Rain barrels
- Rainwater collection systems

Photo shows a garden rainwater tank in the shape of a column.

# Rain barrels

It is a container that holds rainwater discharged from a building roof:

- the simplest implement for rainwater collection and storage
- the rainwater is received through gutters conected to a downspout
- inexpensive
- can be installed at multiple downspouts
- volume: 30–100 gallons (114–380 litres)
- irrigation of shrubs and landscaping

# Rain barrels

The photographs present a very simple rainwater collection system. Rainwater from the roofs of the garage flows down into the gutter and is then collected in a barrel. The barrel is placed at a certain height above ground level. This allows to take water from it through the tap for watering the garden.

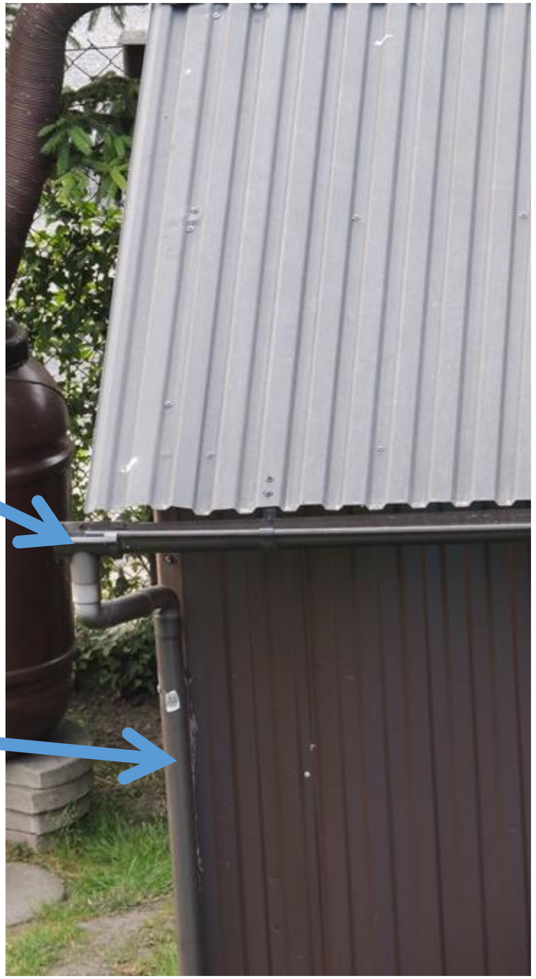
# Elements of the gutter system

Gutter

a shallow trough fastened beneath the edge of a roof to catch drained rainwater

Downspout

a pipe to carry rainwater from a roof to a drain or to ground level



The picture presents elements of the gutter system.

# Other elements of the gutter system

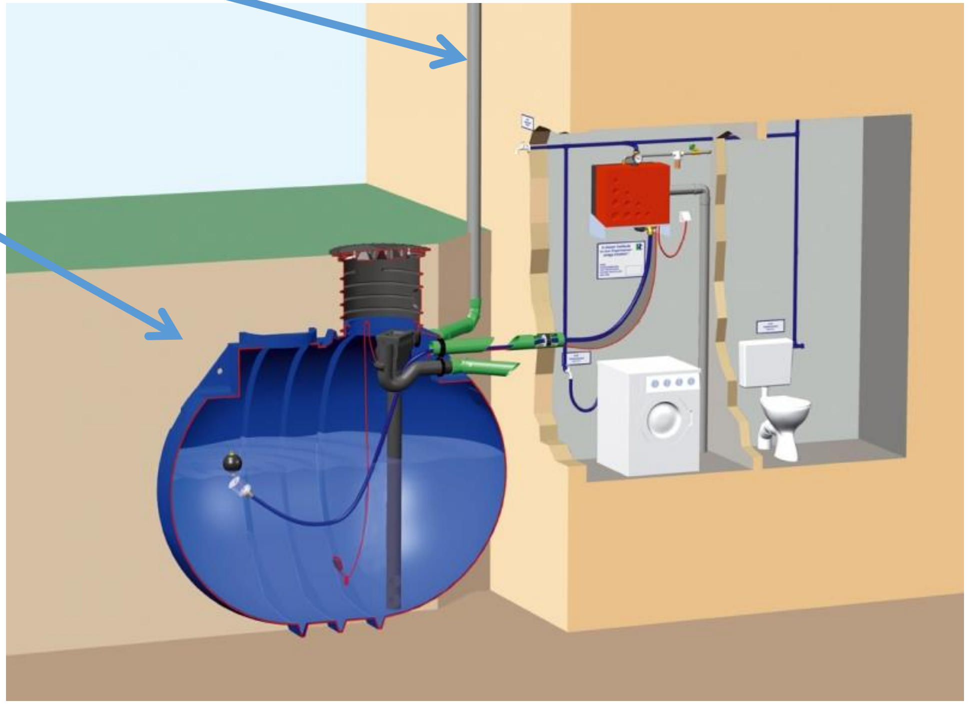
The beginnings of gargoyle downspouts date back to the days of Pharaoh Niuserre (2450–2325 BCE).

One of the many gargoyles of the Notre Dame cathedral in Strasbourg, France.

# Rainwater collection systems

- a rainwater harvesting system that discharges collected rainwater into a holding tank through the use of gutters connected to roofs, downspouts, and drains
- aboveground or below ground storage tanks/holding tanks
- volume of tanks: 1,000–40,000 gallons (4,000–150,000 litres)
- material of tanks: metal, plastic, wood, concrete
- non-potable use and potable use (after treatment)

# Elements of rainwater collection system




The drawing shows a way of delivering rainwater to a single-family building. The shown system uses the rainwater unit.

*Source: zagospodarowanie-wody-deszczowej.pl*

# Greywater versus blackwater

**GREYWATER (GRAYWATER)** – wastewater that do not come into contact with or contain fecal matter or food solids. It comes from showers, baths, lavatories, and clothes washing machines.

**BLACKWATER** – wastewater that has come into contact with or contains fecal matter or food solids. It is generated from dishwashers, kitchen sinks, urinals, water closets. It is not suitable for reuse.

**Greywater** comprises **60% to 80%** of residential wastewater, while **blackwater** covers the remaining **20% to 40%.**

# Greywater

WASHBASIN & URINAL

- greywater is directed through piping and into a holding tank for reuse
- could contain pathogens that could be harmful to humans
- care must be taken to prevent a cross connection with the potable water system!!!
- single – fixture greywater systems

The picture presents an example of an integrated plumbing fixture. Here, a washbasin is integrated with an urinal. The photograph was taken at an exhibition at the Poznań International Fair by J. Bąk.

# Single – fixture greywater systems

- may be used in certain areas of a building
- sometimes used in restrooms
- a simplified system
- reduced possibility of cross contamination

# Greywater

Washbasin & water closet


*Photo by W. Dąbrowski*

Washbasin & urinal

*Photo by J. Bąk*

The first example is a washbasin integrated with a flushing toilet bowl. The picture was taken in Japan. The second example is a washbasin integrated with a urinal. It comes from an exhibition at the Poznań International Fair.

Water which is used for washing hands, is used once again for flushing the urinal.

# Blackwater

- much of blackwater is heated for use
- normally heat energy is lost in the sewer
- prior to the final discharge, this wastewater may be sent through a HEAT EXCHANGER to recover its excess heat
- blackwater can be processed into reclaimed water at a treatment plant

# Reclaimed water

It may be used for the following:

- residential and commercial landscaping
- recreational field irrigation
- fire protection through reclaimed water fire hydrants
- commercial uses (window washing, high – volume car washing)
- cooling towers
- other

# Low – flow plumbing fixtures and appliances

- aerators, atomizers
- flow restrictors
- flow regulators
- low – flow faucets
- low – flow water closets and urinals
  - ✓ special types of flush devices
- other solutions

Low-flow water closets and urinals:

- dual-flush water closets
- ultra-low flow water closets
- ultra-low flow urinals

# AERATORS and other endspouts

- with restrictor

- with flow regulator

*Source: sklep.pge.fc.pl/perlator-z-regulowanym-katem-wyplywu-ssr-hc-pca-50-lmin-m24x1-p-106.html*

*Source: neoperl.net/oem/products/aerators/watercoloaurs.html*

# PCA technology

low pressure normal pressure high pressure

*Source: neoperl.net/oem/products/aerators/watercolours.html*

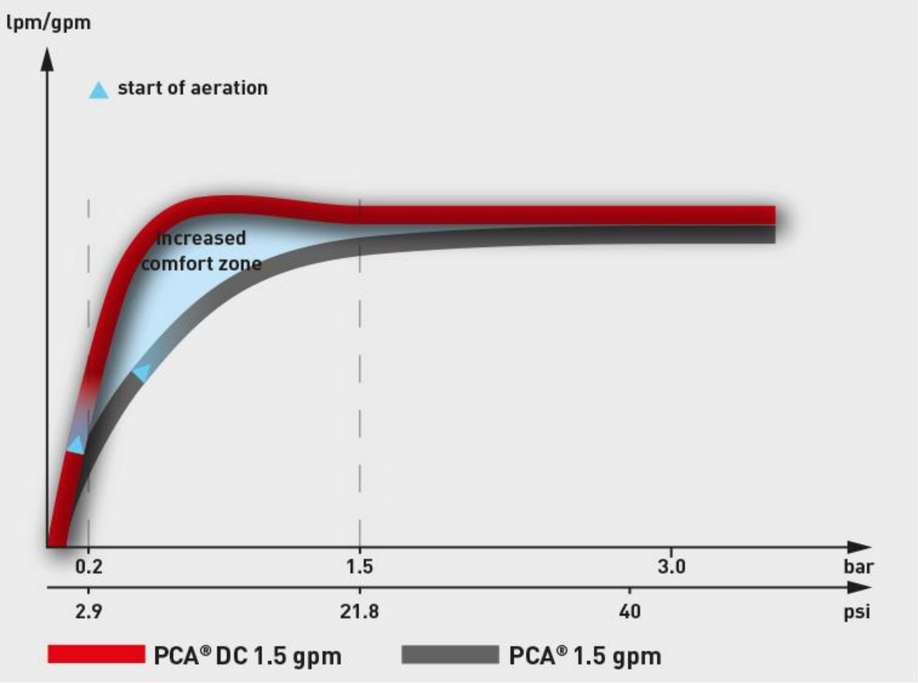
# Types of streams

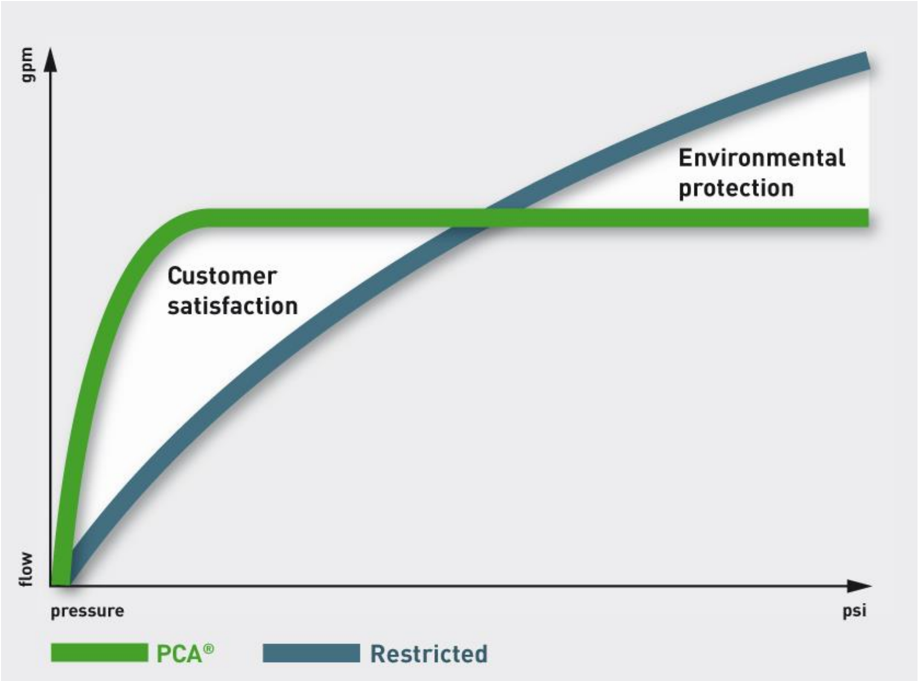
The photograph presents different types of streams. These include aerated stream, laminar stream and other.

*Source: neoperl.net/en/oem/products/aerators/stream.html*

# PCA DC vs. PCA

The graphs show differences in the water flow rate depending on the pressure in the installation, of by using different end spouts (with restrictor, PCA and PCA DC).




*Source: neoperl.net/oem/products/aerators/watercolours.html*

# Regulators and restrictors for showers

RESTRICTOR
assembly between the shower handset and the hose

FLOW REGULATOR FOR SHOWERS
assembly between the shower mixer and the hose

*Source: savinga.pl/regulatory-prysznicowe/38-regulator-prysznicowy-ecovand-ecr-40-lmin.html*

# Atomizers

Single Jet

Triple Jet

Triple Jet M24 x 1.5

Outflow: even 0.1 l/min

*Source: neoperl.net/oem/products/aerators/productlines/atomizer.html*

# Low flow faucets

- single handle faucet
- electronic faucet
- other

# Economical and efficient flushing

- Traditional flushing button

- Dual flush system
- Other solutions

- Flushing button with start and stop function

*Sources: lazienki-szydlowski.pl/tece-loop-przycisk-splukujacy-ze-szkla-do-pisuaru-szklo-biale-przycisk-bialy-9-242-650.html; grohe.pl/pl_pl/skate-przycisk-uruchamiajcy-38573000.html*

# Other solutions

- Low flow headshowers

It has a Venturi nozzle that generates a flush with a high flushing force.

*Source: savinga.pl/sluchawki-prysznicowe-z-dysza-venturiego/53-sluchawka-prysznicowa-ecovand-saver-dual-60-lmin.html*

- Saving "weights" for cisterns

*Source: savinga.pl/produkty-do-toalety/69-oszczedzacz-ecovand-wc-stop.html*

# Waterless fixtures

- waterless urinals
- composting toilets

# Waterless urinals

A waterless urinal has been developed to:

- conserve water
- promote cleanliness
- lower maintenance
- repair bills
- create odor-free restrooms.

There are several different types of waterless urinals. Some contain a liquid sealant or a special cartridge. Above, the principle of functioning of one of the available types of waterless urinals is described.

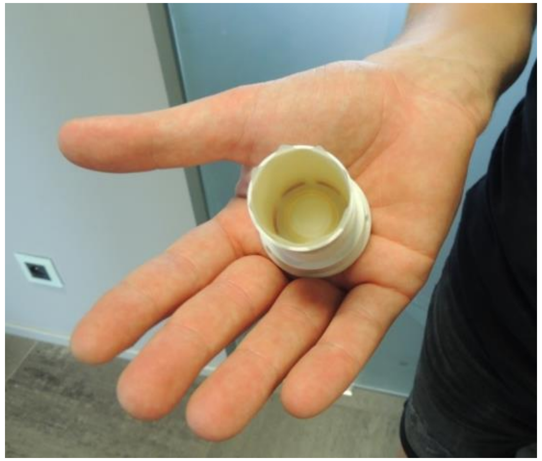
# Waterless urinals

REMOVABLE CARTRIDGE with a floating liquid sealant in the drain opening.

Cartridge and sealant fluid must be periodlically removed and replaced by staff.

Liquid waste passes through a floating liquid sealant, which closes to seal off odors, and into the drainage pipe.

# Waterless urinal



The pictures present an example of a trap for waterless urinals.

# Composting toilets

The pictures show a composting toilet. The photograph was taken in Sweden. It is not an exhibition. This plumbing fixture is in normal use.
The special design of the toilet bowl allows separate collection of yellow and black wastewater.

# Other solutions: potable water from air humidity

The pictures show different appliances used for producing potable water from air humidity.

*Source: ecoloblue.com/atmospheric-water-generator*

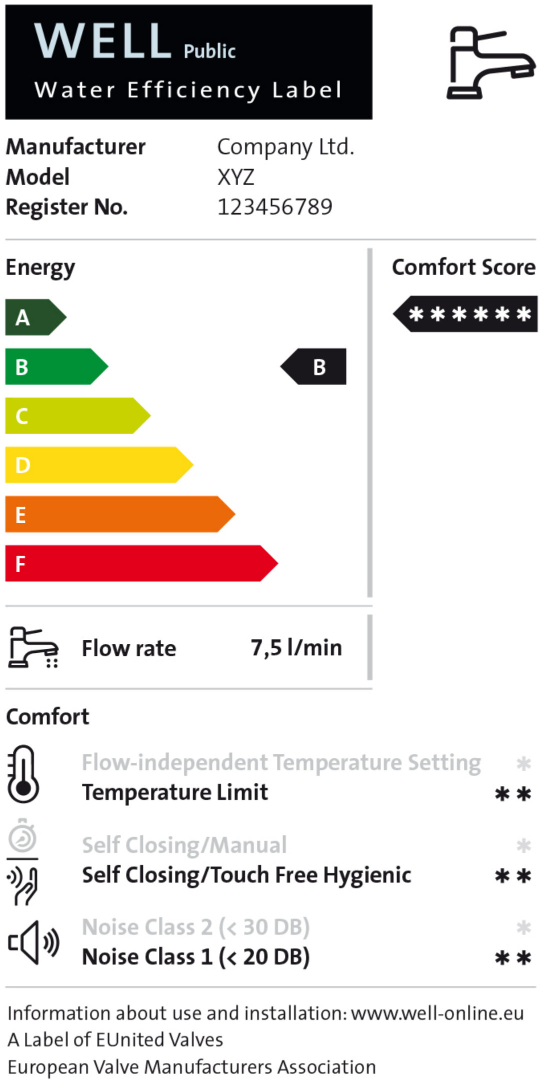

*Source: drinkableair.com/product/chameleon*

# Assessment systems for fixtures

- WELL
- WaterSense Program
- WEPLS (Water Label)
- WELS (1)
- WELS (2)

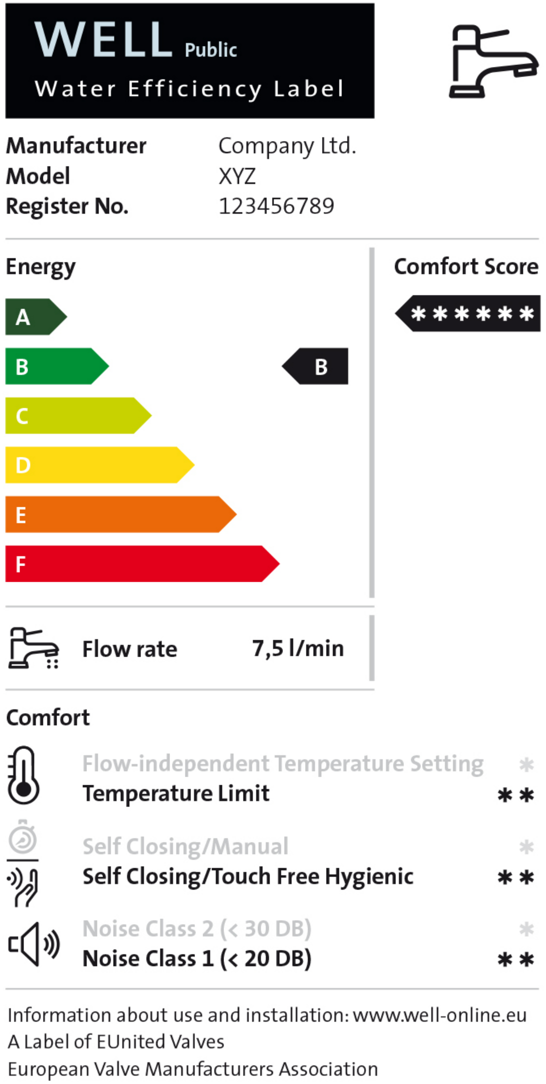
# Well – water efficiency label

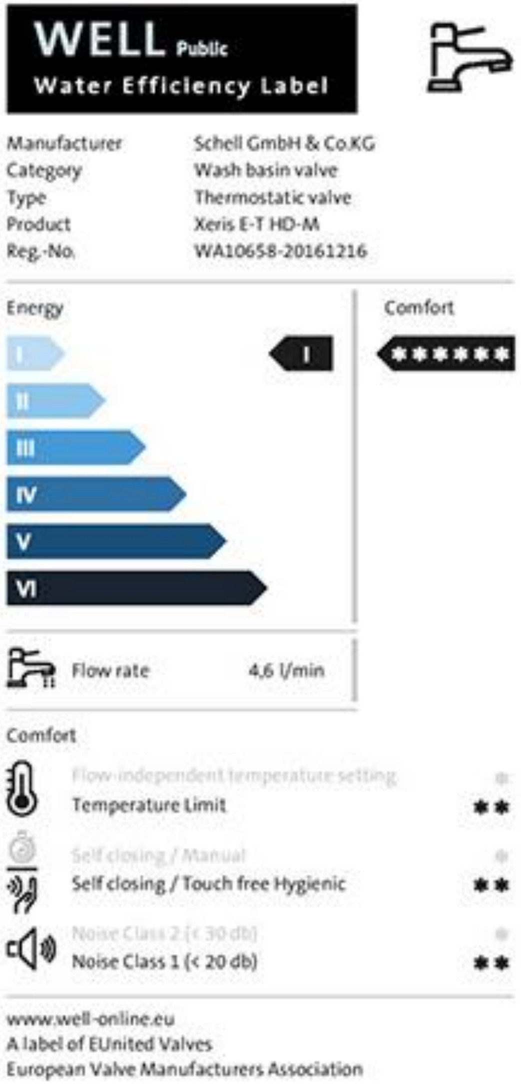
WELL or Water Efficiency Label is a voluntary classification system used in Europe. It assesses valves of washbasins, bidets, showers, showerheads, shower hoses, toilet and urinal flushing systems and accessories. The fittings are graded using letters on a scale from A to F, and with asterisks. The highest possible result is the letter A and 4 stars for households or 6 stars for public places.




*Source: well-online.eu/cms/upload/pictures/177_WELL_LABEL_public_wasch_1603.jpg*

# Well labels




*Sources: well-online.eu/cms/upload/pictures/177_WELL_LABEL_public_wasch_1603.jpg; installatieenbouw.nl/artikel/schell-introduceert-water-efficiency-label-well-kranen/*

# WaterSense Program

- was created by the Environmental Protection Agency (EPA) in partnership with plumbing fixtures manufacturers
- creates and certifies water efficient fixtures
- products bearing the WaterSense label are generally at least 20 percent more water-efficient than similar products in the marketplace
- the WS label can be found on lavatory faucets, showerheads, toilets, urinals

# WaterSense Program Labels

Label for products that have been independently certified to meet EPA WaterSense criteria

Label for promotional partners to encourage use of WaterSense labeled products, services, and homes

*Source: epa.gov/watersense/watersense-label*

# Wepls or water efficient product labeling scheme

WEPLS or Water Efficient Product Labeling Scheme is a voluntary classification system used in Europe. It assesses bathtubs, toilets, reservoirs, faucet sets, showerheads, shower controls, controls in the urinal, kitchen valves, gray water recovery systems, electric showers, replacement toilet flushing units, flow regulators and independent toilet bowls. They are rated on the basis of flow, the largest classified is 13 l/min and the best result is obtained after reaching a capacity of 6 l/min.


*Source: thekbzine.com/pages/3495/bmas_wepls_water_label_is_adopted_in_europe/*

# WELS or water efficiency labeling and standards

WELS or Water Efficiency Labeling and Standards is a mandatory classification system used in Australia. It assesses showers, flow controllers, faucet sets, toilets, urinals and appliances such as washing machines and dishwashers. The highest score possible is 6 stars.


*Source: waterrating.gov.au*

# Wels water efficiency labelling scheme

Started in 2009, the Mandatory Water Efficiency Labeling (Mandatory WELS) is a grading system with 0/1/2/3 tick rating denoting the water efficiency level of a product. Currently, Mandatory WELS (Mandatory WELS) covers taps and mixers, dual-flush low capacity flushing cisterns (LCFCs), urinal flush valves and waterless urinals (1/2/3 tick rating) and washing machines (2/3/4-tick rating).


*Source: pub.gov.sg/wels/labelratings/typesoflabel*

# GREEN building rating systems

Multi-criteria investment assessment systems aid in solving many problems.

- allow analysis and evaluation of various issues, including those related to the environment
- encourage investors to devote more funds to environmental issues.

These include systems such as:

BREEAM – Building Research Establishment Environmental Assessment Method,

DGNB – certificate of the German Sustainable Building Association,

HQE (High Quality of Environment) certification scheme,

LEED – Leadership in Energy and Environmental Design

WELL Building Standards certification system developed by the International WELL Building Institute.

# BREEAM system (Building Research Establishment Environmental Assessment Method)

- certificates may be issued for single buildings, environments and infrastructure projects
- the following categories are assessed during the certification process: energy, health and well-being, innovation, land use, materials, management, pollution, transport, waste and water
- certificates issued for existing buildings (BREEAM In-Use) require renewal, while certificates for new buildings are issued indefinitely (final certificates).

# BREEAM system (Building Research Establishment Environmental Assessment Method)

- for each of the categories, the percentage of achieved points (called credits) is calculated in relation to those possible to achieve.
- each category has its own weight, by which the obtained percentage result is multiplied. The sum of partial results gives the final grade
- the object can get a grade from acceptable (but only in the In-Use scheme) through pass, good, very good, excellent, up to the highest score – outstanding
- in addition to the appropriate number of points, critical requirements and minimum requirements depending on the given level of certification should also be met

# LEED leadership in energy and environmental design

- began in 1994
- certification based on a point system
- covers type of construction project, use, energy efficiency, materials selection, indoor environment quality, other
- it addresses sustainable development
- certification level: certified, silver, gold, platinum
- sustainable plumbing practices may result in obtaining LEED credits for water efficiency and renewable energy resources

# LEED certification levels


*Source: everbluetraining.com/sites/default/files/leed-certification-levels_0.jpg*

# Part 11

# *Sewage installation – projects*

*Joanna Bąk*

# OUTLINE OF THIS PART:

- Introduction
- Basic definitions
- PN-EN 12056-2 – discussion
- Layout of sanitary pipework (team work)
- Calculation of sanitary pipework (individual work)
  - ✓ Fixture drain
  - ✓ Stack pipes
  - ✓ Horizontal drain
- Technical description of project

Projects from sanitary installations are divided into two parts. The first part concerned the internal water system. The second part, which we start today, concerns the sewage installation.

The activities of  the second part of the project section are divided into several parts. The first of these is "Introduction". The following sections present the characteristics of sanitary drainage systems. In particular, these are basic definitions of elements of sewage installation.

# Sanitary drainage system

It is a system of sanitary drainage pipes and fittings that conveys wastewater and waterborne waste from plumbing fixtures and appliances to a sanitary sewer or other point of disposal.

WASTE PIPE – conveys only liquid waste that is free of fecal matter

SOIL PIPE – conveys the discharge of water closet or other similar fixtures, containing fecal matter, with or without discharge of other fixtures

Scheme of sewage installation – see p. 360

# Plumbing fixtures sanitary facilities

A plumbing fixture (or sanitary facility) is any device (or receptacle/reservoir) that is connected (permanently or temporarily) with the water distribution system, requires the supply of drinking water (pottable water) and discharges sewage (directly or indirectly) into a sanitary drainage system.

Another name used for "plumbing fixtures" is "sanitary facilities".

# Plumbing fixtures and appliances

There are many different plumbing fixtures and appliances. They differ from each other due to their function. In addition, each type of plumbing fixture usually has several varieties and models. The same concerns to appliances.

Plumbing fixtures are:

- lavatories
- sinks
- bathtubs
- showers as one-piece assemblies and shower bases
- water closets
- Bidets
- urinals
- drinking fountains
- and integrated facilities and also
- laundry trays
- service sinks
- mop basins.

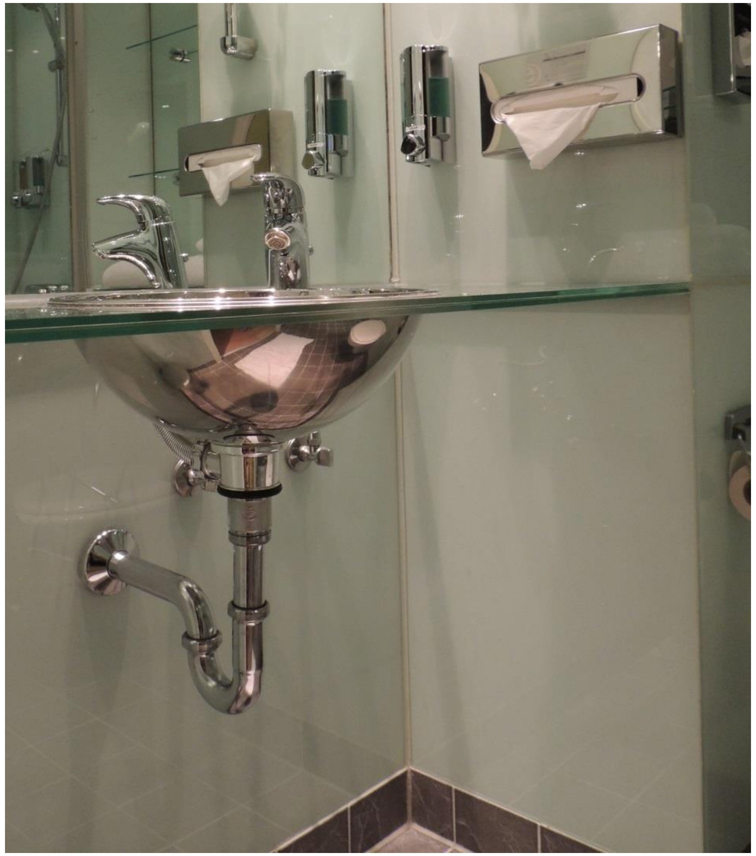
Between appliances are devices such as:

- food waste disposers
- dishwashers
- washing machines
- water coolers
- water softeners
- water filters
- water heaters.

# Plumbing traps

All fixtures that are directly connected to the sanitary drainage system must have liquid – seal traps. Its construction prevents passage of air/gas through the pipe and at the same time permits the flow of wastewater through the pipe to the sanitary drainage system.

# Plumbing traps



The pictures present P-traps.

# Fixture drain and branch

Firstly, wastewater and waterborne waste flows through a fixture trap. The wastewater then enters a **fixture drain**.

FIXTURE DRAIN – drainage pipe that extends from the trap of the fixture to the junction of the next drainage pipe.

When multiple fixture are on the same floor, wastewater flows into a horizontal branch.

HORIZONTAL BRANCH – soil/waste pipes that receive the discharge from fixtures on the same floor and extend horizontally from a stack.

Angle inlet – see p. 366
Inclined inlet – see p. 367

# Stack

Any vertical line of soil/waste/vent pipe extending through one or more stories.

- WASTE STACK
- SOIL STACK (SOIL PIPE)
- VENT STACK (vertical pipe that provides circulation of air to and from the drainage system)

but

the STACK VENT is an extension of the waste/soil stack that runs up through the roof to the exterior (above the highest horizontal drain connected to the stack).

Vent Stack vs. Stack Vent – see p. 383
Vent Pipe – see p. 384
Cleanout – see p. 387
Horizontal drain/building drain – see p. 389
Sewer service line/building sewer – see p. 390
Sanitary sewer/sewer main – see p. 395
Scheme of sewage installation – see p. 360

# Tables connected to PN-EN 12056-2 2002

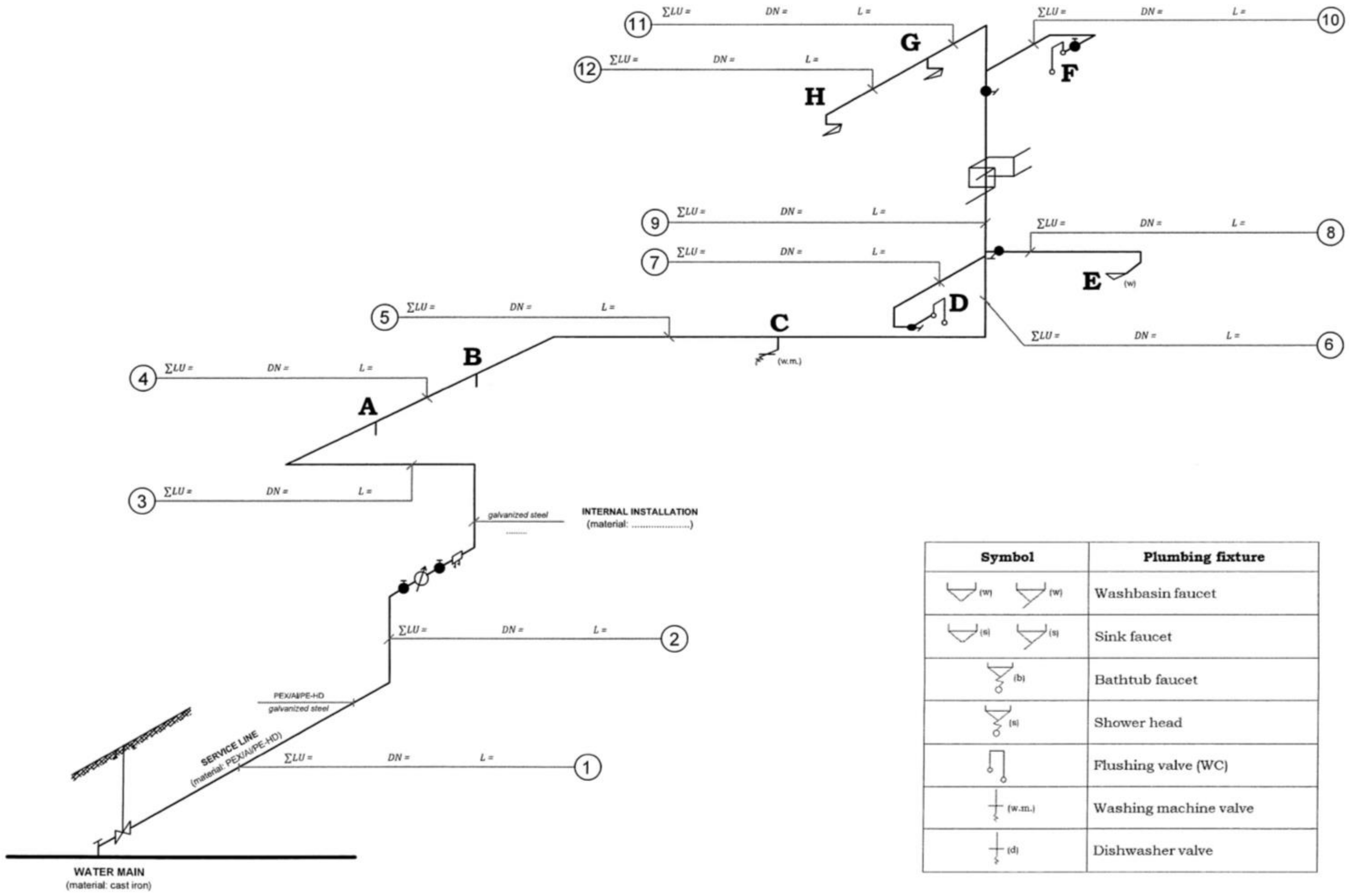
Gravity drainage systems inside building, please see pages: 410, 416, 417, 418
The method considered both the Polish Norm and the European Norm – please see p. 427

# Typical frequency K coefficient

| Type of building | K |
|---|---|
| Use discontinuous, e.g. in an apartment, office, guesthouse | 0.5 |
| Periodic use, e.g. in a hospital, school, restaurant, hotel | 0.7 |
| Collective use, e.g. public toilets and showers | 1.0 |
| Special use, e.g. laboratories | 1.2 |

*The table according to PN-EN 12056:2002*

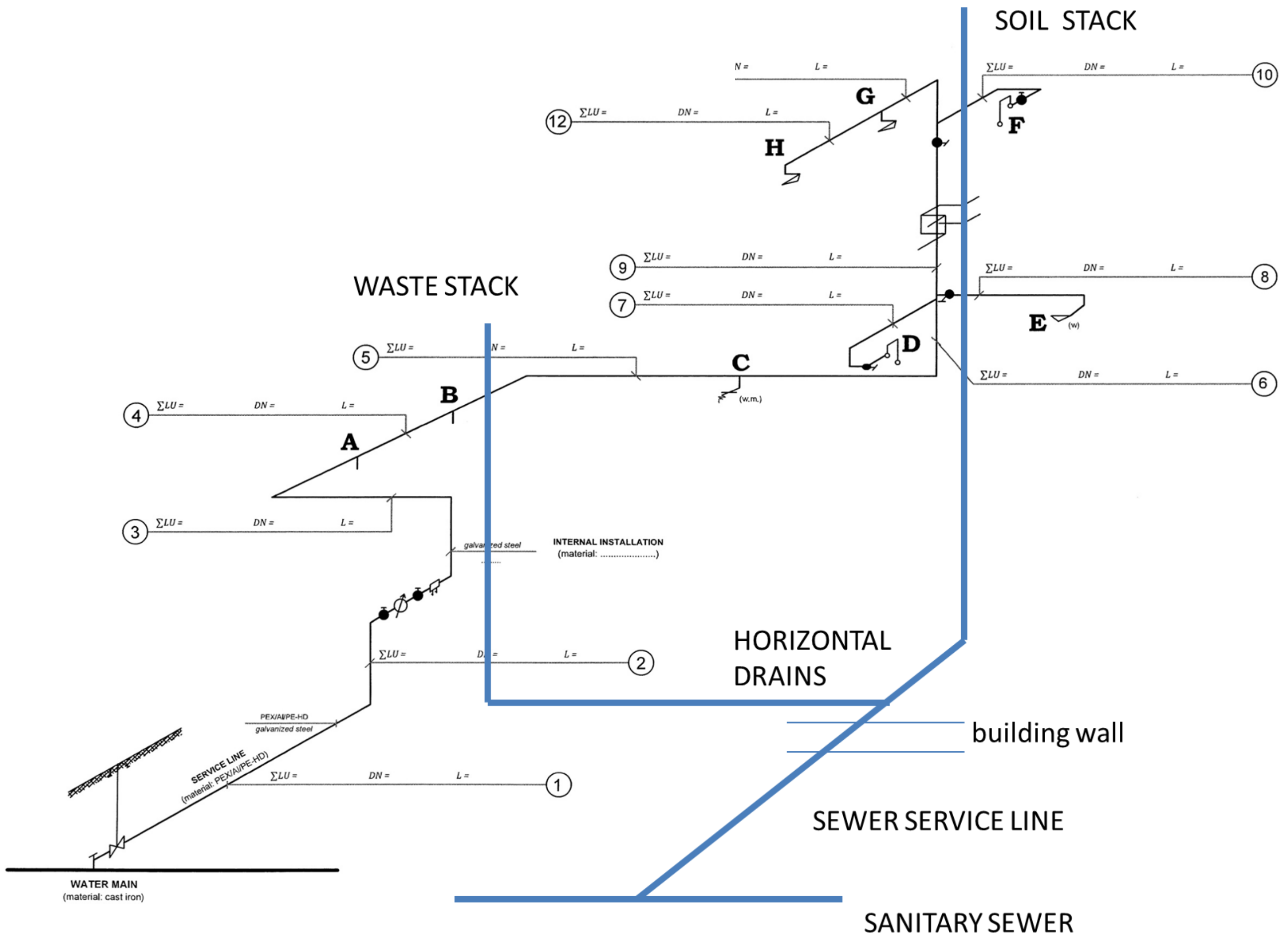
# Axonometric view of water installation




| Symbol | Plumbing fixture |
|---|---|
| (w) (w) | Washbasin faucet |
| (s) (s) | Sink faucet |
| (b) | Bathtub faucet |
| (s) | Shower head |
| | Flushing valve (WC) |
| (w.m.) | Washing machine valve |
| (d) | Dishwasher valve |

*Source: CUT resources*

# Axonometric view of sewage installation




*Source of background of image: CUT resources*

# Sewage installation calculations

Steps:

1) Determine the discharge unit for every plumbing fixture
2) Size the fixture drains
3) Calculate the flow rates for stacks
4) Size the stacks (soil stack and waste stack)
5) Calculate the flow rate for horizontal drains
6) Size horizontal drains

Table representing Sizing of fixture drains – see p. 427
Typical diameters of fixtures drains – see p. 420

Table. Plumbing fixture. Type of system: I

| Plumbing fixture | Type of system<br>I<br>DU l/s |
|---|---|
| Washbasin | 0.5 |
| Shower without a stopper | 0.6 |
| Shower with a stopper | 0.8 |
| Bathtub | 0.8 |
| Sink | 0.8 |
| Dishwasher (domestic) | 0.8 |
| Washing machine up to 5 kg | 0.8 |
| Flushing toilet with flushing cistern  6 l | 2.0 |
| Flushing toilet with flushing cistern 7.5 l | 2.0 |
| Flushing toilet with flushing cistern 9 l | 2.5 |

*According to PN-EN 12056: 2002.*

# Hydraulic capacity of fixture drain  without ventilation

| $Q_{max}$ | System I |
|---|---|
| l/s | DN [mm] |
| 0.4 | not recommended |
| 0.5 | 40 |
| 0.8 | 50 |
| 1 | 60 |
| 1.5 | 70 |
| 2 | 80* |
| 2.25 | 90** |
| 2.5 | 100 |

* without flushing toilets
** not more than two flushing toilets and total change of direction not more than 90 degrees

*According to PN-EN 12056: 2002.*

# Sizing of stacks

| Stack | Symbols of plumbing fixtures that have an outlet in the stack | Sum of DU | K | Flow rate | Diameter of the stack |
|---|---|---|---|---|---|
| SOIL STACK: | | | | | |
| WASTE STACK: | | | | | |

Typical frequency K coefficient – see p. 519
The method considered both the Polish Norm and the European Norm – please see p. 427

# Hydraulic capacity of soil/waste stack and minimal diameter of stacks

| SOIL/WASTE STACK DN [mm] | TYPE I | |
|---|---|---|
| | ANGLE INLET Qmax [l/s] | INCLINED INLET Qmax [l/s] |
| 60 | 0.5 | 0.7 |
| 70 | 1.5 | 2 |
| 80 | 2 | 2.6 |
| 90 | 2.7 | 3.5 |
| 100* | 4 | 5.2 |
| 125 | 5.8 | 7.6 |
| 150 | 9.5 | 12.4 |
| 200 | 16 | 21 |

*The table according to PN-EN 12056:2002*

# Horizontal drains and sewer service line

| Horizontal drain | Sum of DU | Flow rate [l/s] | Diameter [mm] |
|---|---|---|---|
| No 1 | | | |
| No 2 | | | |
| No 3 | | | |
| Sewer service line | – | | 150 |

# Hydraulic capacity of horizontal drains

| Slope [cm/m] | DN 100 | | DN 124 | | DN 150 | | DN 200 | | DN 225 | | DN 250 | | DN 300 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] | $Q_{max}$ [l/s] | V [m/s] |
| 0.5 | 1.8 | 0.5 | 2.8 | 0.5 | 5.4 | 0.6 | 10.0 | 0.8 | 15.9 | 0.8 | 18.9 | 0.9 | 34.1 | 1.0 |
| 1.0 | 2.5 | 0.7 | 4.1 | 0.8 | 7.7 | 0.9 | 14.2 | 1.1 | 22.5 | 1.2 | 26.9 | 1.2 | 48.3 | 1.4 |
| 1.5 | 3.1 | 0.8 | 5.0 | 1.0 | 9.4 | 1.1 | 17.4 | 1.3 | 27.6 | 1.5 | 32.9 | 1.5 | 59.2 | 1.8 |
| 2.0 | 3.5 | 1.0 | 5.7 | 1.1 | 10.9 | 1.3 | 20.1 | 1.5 | 31.9 | 1.7 | 38.1 | 1.8 | 68.4 | 2.0 |
| 2.5 | 4.0 | 1.1 | 6.4 | 1.2 | 12.2 | 1.5 | 22.5 | 1.7 | 35.7 | 1.9 | 42.6 | 2.0 | 76.6 | 2.3 |
| 3.0 | 4.4 | 1.2 | 7.1 | 1.4 | 13.3 | 1.6 | 24.7 | 1.9 | 38.9 | 2.1 | 46.7 | 2.2 | 83.9 | 2.5 |
| 3.5 | 4.7 | 1.3 | 7.6 | 1.5 | 14.4 | 1.7 | 26.6 | 2.0 | 42.3 | 2.2 | 50.4 | 2.3 | 90.7 | 2.7 |
| 4.0 | 5.0 | 1.4 | 8.2 | 1.6 | 15.4 | 1.8 | 28.5 | 2.1 | 45.2 | 2.4 | 53.9 | 2.5 | 96.9 | 2.9 |
| 4.5 | 5.3 | 1.5 | 8.7 | 1.7 | 16.3 | 2.0 | 30.2 | 2.3 | 48.0 | 2.5 | 57.2 | 2.7 | 102.8 | 3.1 |
| 5.0 | 5.6 | 1.6 | 9.1 | 1.8 | 17.2 | 2.1 | 31.9 | 2.4 | 50.6 | 2.7 | 60.3 | 2.8 | 108.4 | 3.2 |

*According to PN-EN 12056: 2002. The filling depth of pipe is 50%.*

*Source: Chudzicki, Sosnowski 2011*

# Technical description of project

- what was designed (sewage installation)
- which plumbing fixtures have been included
- according to which regulations were the calculations carried out? (PN-EN 12056)
- which type of system (I)
- how many stacks
- what type of stacks (waste/soil)
- which diameters were chosen for which sections
- pipe material

# Scope of the project

- technical description
- 3 completed tables
- diagram of the sewage installation in Autocad with description of the dimensioned sections

# Issues for the test

- the differences between soil stack, waste stack and vent stack
- definition of stack vent
- scheme of sewage installation and basic definitions (fixture drain, stack, horizontal drain, sewage service line, cleanout, trap)
- calculation of sanitary pipework (fixture drain, stack pipes, horizontal drain) according to EN 12056
- typical dimension of fixture drain
- equation for wastewater flow rate $Q_{ww}$
- values of frequency coefficient K

# Laboratory exercise 1

# *Introduction*

*Renata Sikorska-Bączek*
*Dorota Skrzyniowska*

# OUTLINE OF LABORATORY EXERCISE:

- Mechanical ventilation – the main aim
- Mechanical and natural ventilation
- Ventilation system in building
- Types of mechanical ventilation
- Duct work, duct accessories
- Definition of Pitot ( Prandtl) tube
- Bernoulie's equation style

A mechanical ventilation system is where the air is supplied or extracted from the building or both by a fan by using **air terminal devices**, ducts and roof/wall **outlets**.

In single exhaust mechanical systems, the air enters the dwelling through externally mounted air transfer devices, windows and leakages.

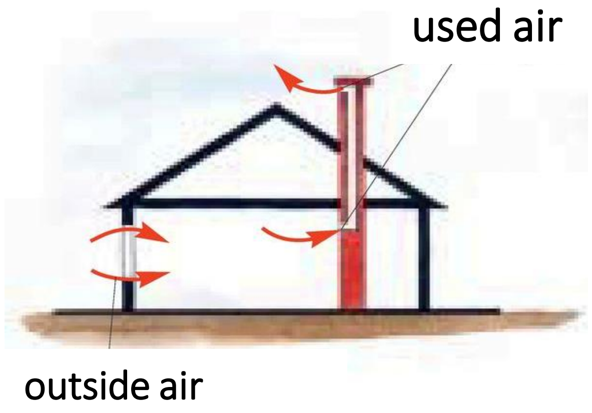
# Mechanical ventilation – the main aim

## Remove ‚stale' air and replace it with ‚fresh' air

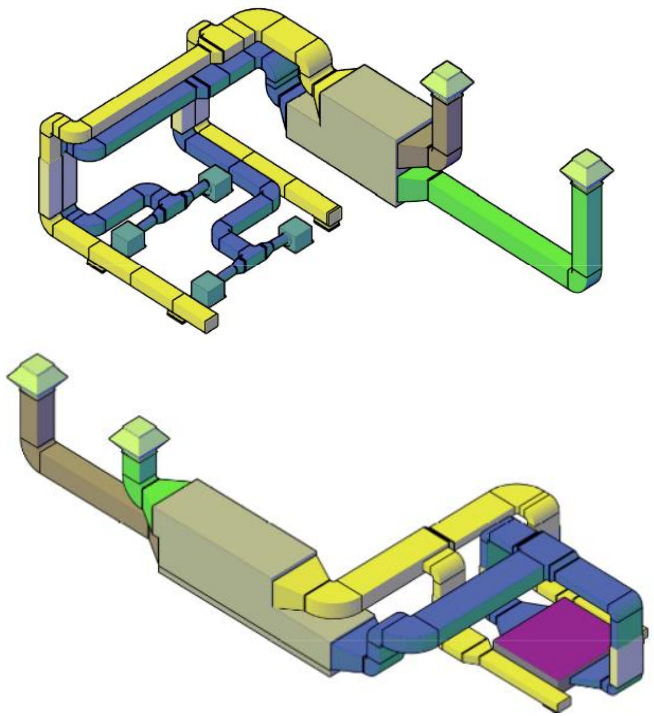
1. Moderate internal temperatures
2. Moderate internal humidity
3. Replenish oxygen
4. Reduce the accumulation of moisture, odours, bacteria, dust, carbon dioxide, smoke and other contaminants that can build up during occupied periods
5. Create air movement which improves the comfort of occupants

# Classification of ventilation in buildings

**natural**




**mechanical**



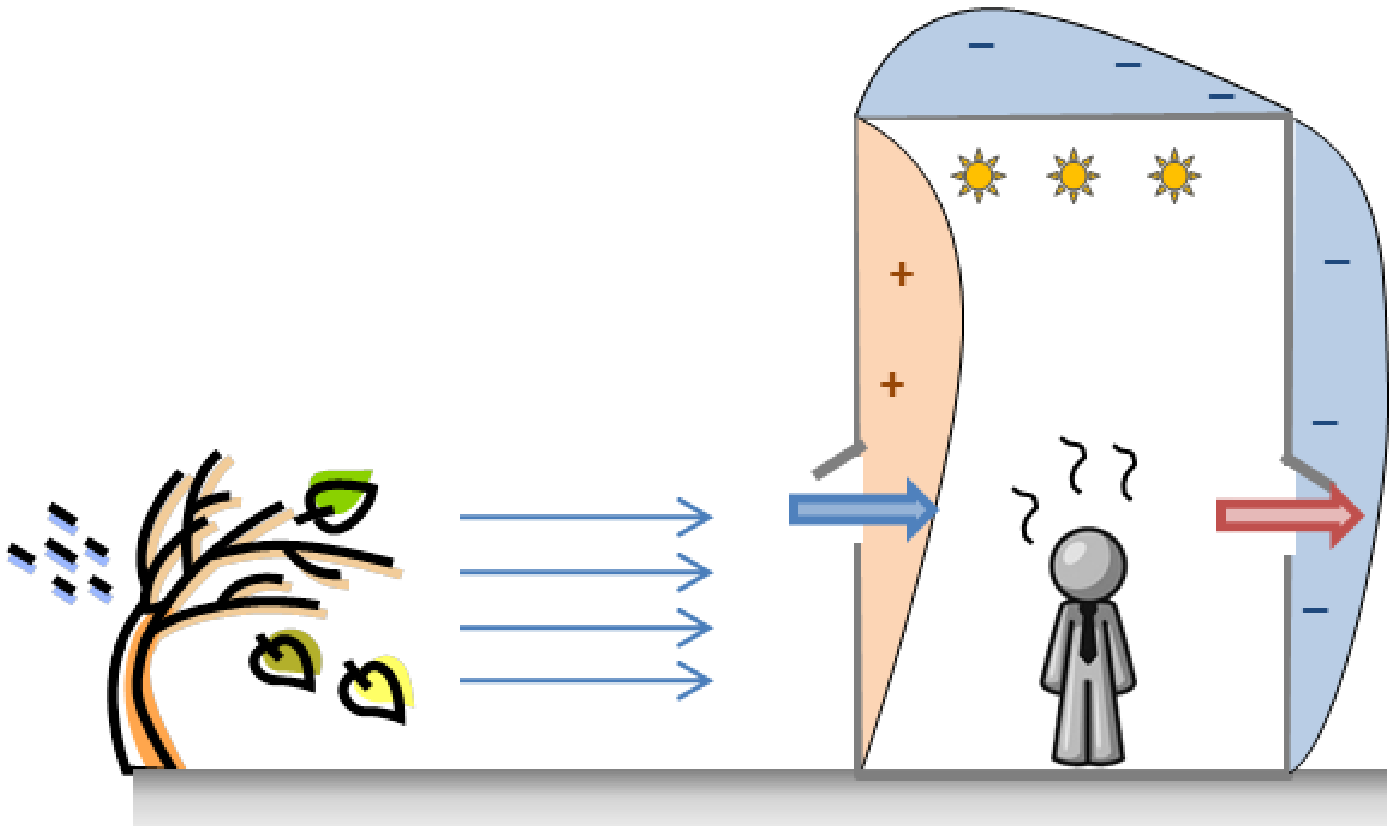
# Mechanical and natural

- is driven Mechanical ventilation
- by fans or mechanical plant

Natural ventilation

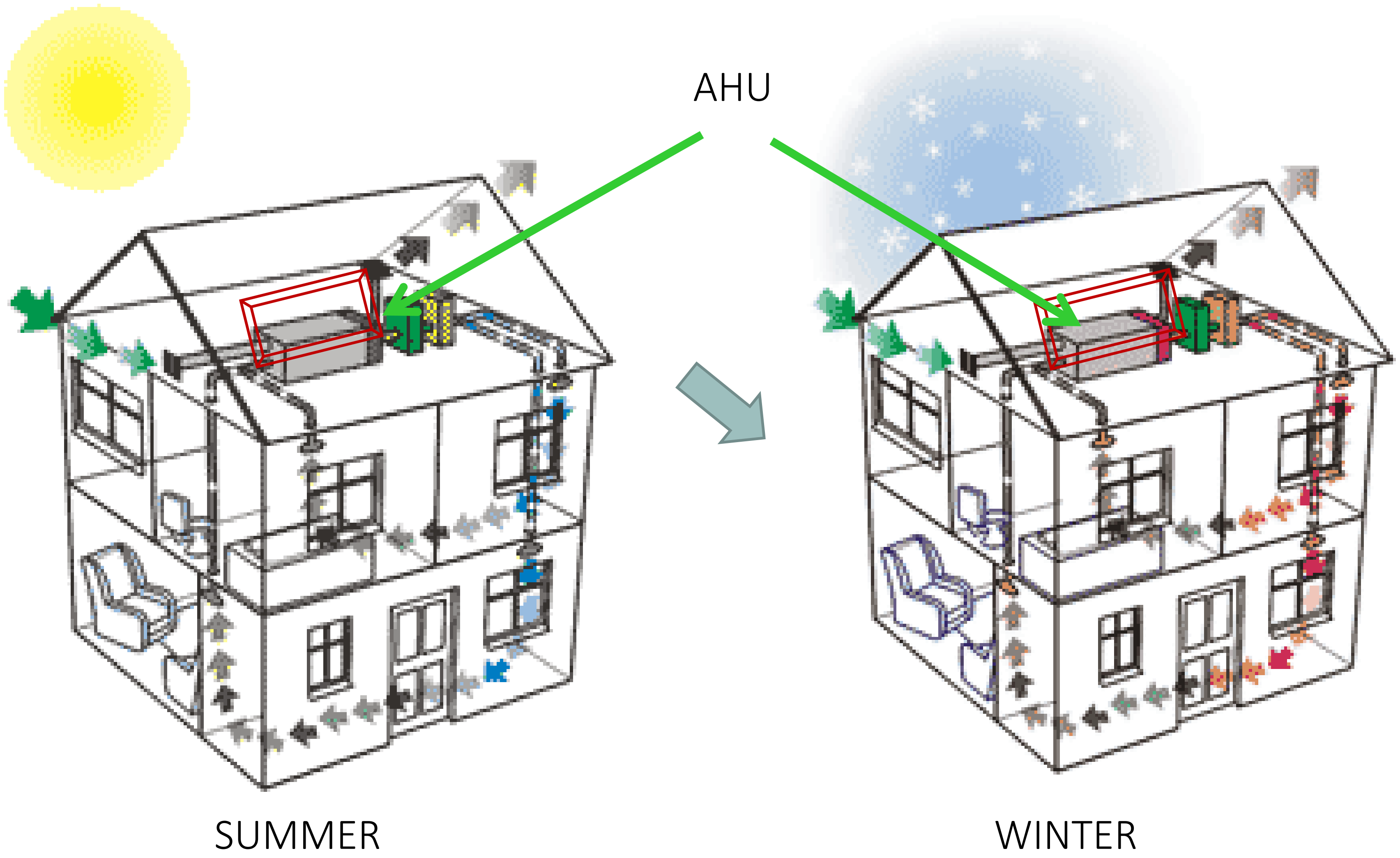
- is driven by pressure differences between one part of a building and another
- or pressure differences between the inside and outside
- or temperature differences between the inflowing and outflowing air

# How does natural ventilation work?




*Source: coolvent.mit.edu/intro-to-natural-ventilation/basics-of-natural-ventilation/*

# Ventilation system in building



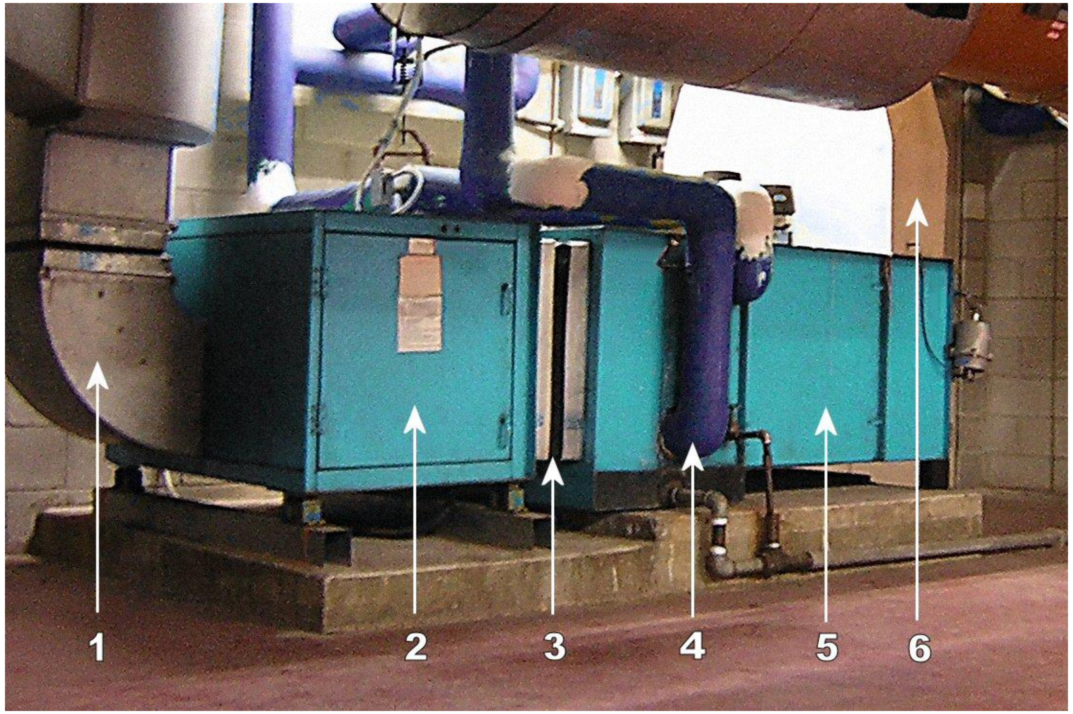
# Why we cannot use natural ventilation

1. The building is too deep to ventilate from the perimeter
2. Local air quality is poor, for example, if a building is next to a busy road
3. Local noise levels mean that windows cannot be opened
4. The local urban structure is very dense and shelters the building from the wind
5. Privacy or security requirements prevent windows from being opened
6. Internal partitions block air paths
7. The density of occupation, equipment, lighting and so on creates very high heat loads or high levels of contaminants

# Types of mechanical ventilation

1) circulation system
2) pressure system
3) vacuum system
4) balanced system
5) local exhaust system

# Typical mechanical ventilation systems for commercial buildings




**AHU – air handling unit**

Air flows from the right to left in this case

1 – Intake duct
2 – Fan compartment
3 – Vibration isolator ('flex joint')
4 – Heating and/or cooling coil
5 – Filter compartment
6 – Supply (recirculated + outside) air duct

*Source: en.wikipedia.org/wiki/Air_handler*

# AHU, HVAC

**AHU + heating, cooling, humidity control**

**HVAC – Heating Ventilation and Air Conditioning**

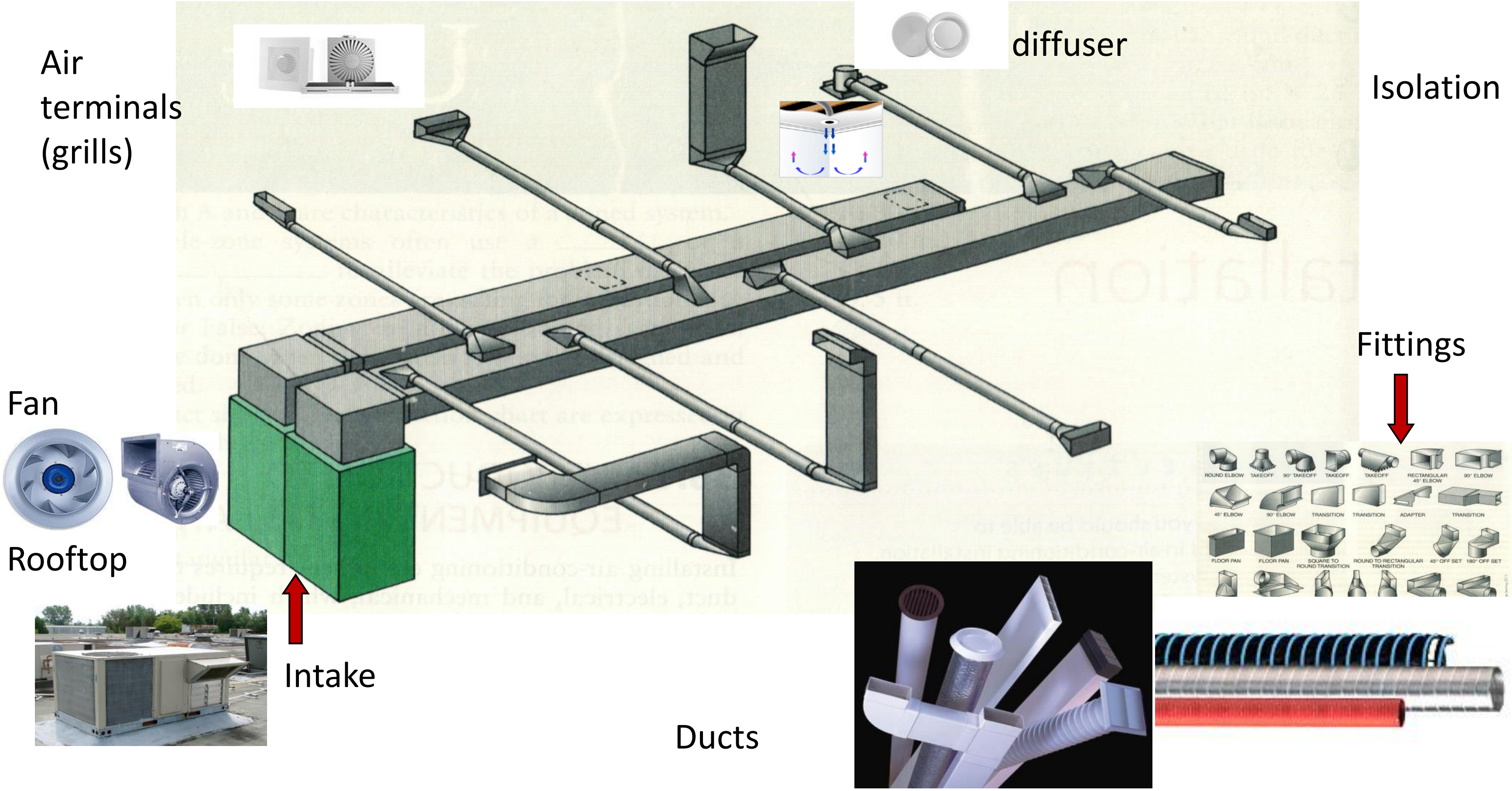
# Building management systems

**BMS – Building Management System:**

Computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems and security systems.

# Ductwork, duct accessories – part of ventilation system

## Air path throughout a building



# Ductwork – materials

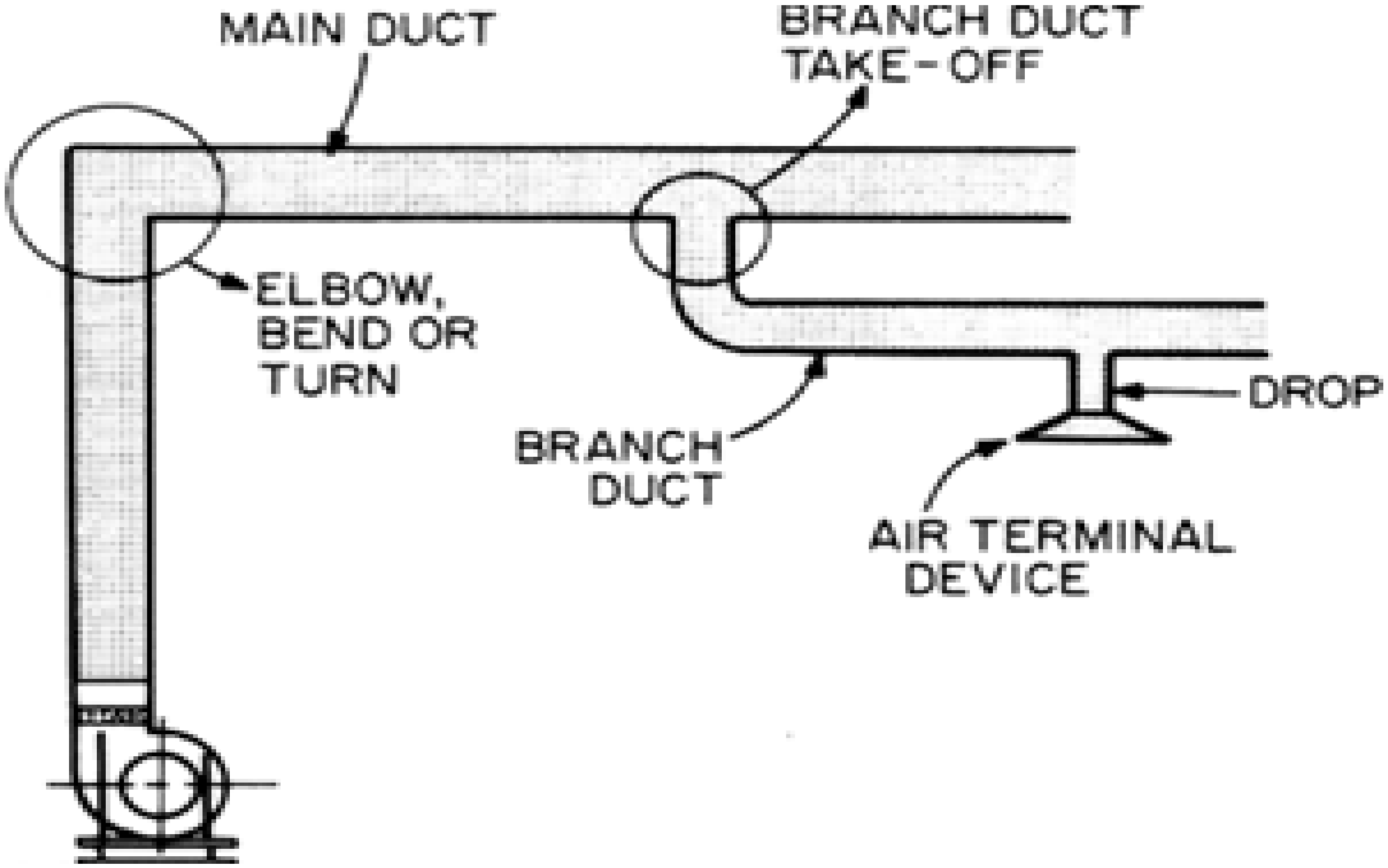
Ducts can be fabricated from range of materials:

1. Galvanised mild steel
2. Aluminium
3. Polyurethane and phenolic foam panels
4. Fibreglass

# Airflow velocity in ducts

| Type of Duck | Comfort Systems | | Industrial Systems | | High Speed Systems | |
|---|---|---|---|---|---|---|
| | m/s | ftm | m/s | ftm | m/s | ftm |
| Main ducts | 4–7 | 780–1380 | 8–12 | 1575–2360 | 10–18 | 1670–3540 |
| Main branch ducts | 3–5 | 590–985 | 5–8 | 985–1575 | 6–12 | 1180–2360 |
| Branch ducts | 1–3 | 200–590 | 3–5 | 590–985 | 5–9 | 985–1575 |

# Air ducts


MAIN DUCT
BRANCH DUCT
TAKE-OFF
ELBOW,
BEND OR
TURN
BRANCH
DUCT
DROP
AIR TERMINAL
DEVICE

# Pitot tube (Prandtl tube)

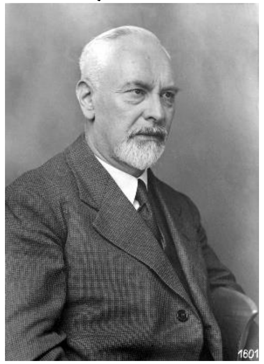
Flow measurement device used to measure fluid flow velocity.

The basic Pitot tube consists of a tube pointing directly into the fluid flow. As this tube contains fluid, a pressure can be measured.

*Source: pressure measurement*

Henri Pitot 1695–1771

French hydraulic engineer



Ludwig Prandtl 1875–1953

German engineer

# Bernoulli's equation states

$p_{stagnation} = p_{statistic} + p_{dynamic}$
$p_{dynamic} = p_{stagnation} - p_{statistic}$

$$\boldsymbol{p_{dynamic}} = \frac{\boldsymbol{\rho\, v^2}}{\mathbf{2}} \text{ [Pa]}$$

where:
v – air flow velocity [m/s]
P – air density in temperature 20°C , $\rho = 1.2$ kg/m$^3$

**Solving that equation for air flow velocity gives:**

$$v = \sqrt[2]{\frac{2(p_{stagnation} - p_{statistic})}{\rho}} = \sqrt[2]{\frac{2\, p_{dynamic}}{\rho}} \approx 1.3\sqrt[2]{p_{dynamic}} \text{ [m/s]}$$

**Volumetric flow of air flowing through the duct is estimated from equation**

$$V = v_a\ F \text{ [m}^3\text{/s], [m}^3\text{/h]}$$

where:
$v_a$ – average air velocity, [m/s]
F – duct surface, [m$^2$]

# Tasks to be carried out

1. Measurement of dimension of ducts (length, width, duct surface)
2. Drawing of installation in axonometric projection
3. Measurement dynamic pressure of air in duct using Pitot (Prandtl) tube
4. Calculation of air flow velocity
5. Creating air flow velocity profile in duct (for different rotational velocity of run)
6. Calculation of volumetric flow of air flowing through the duct

# European standards and Polish standards

1. **PN-EN 15242:2007 – English version: Ventilation for buildings – Calculation methods for the determination of air flow rates in buildings including infiltration** (Wentylacja budynków – Metody obliczeniowe do wyznaczania strumieni objętości powietrza w budynkach z uwzględnieniem infiltracji)
2. **PN-EN 16798-7:2017-07 – English version: Energy performance of buildings – Ventilation for buildings - Part 7: Calculation methods for the determination of air flow rates in buildings including infiltration (Modules M5-5)** (Charakterystyka energetyczna budynków – Wentylacja budynków – Część 7: Metody obliczeniowe służące określaniu strumieni objętościowych powietrza w budynkach, włącznie z infiltracją (Moduł M5-5))

# Laboratory exercise 2

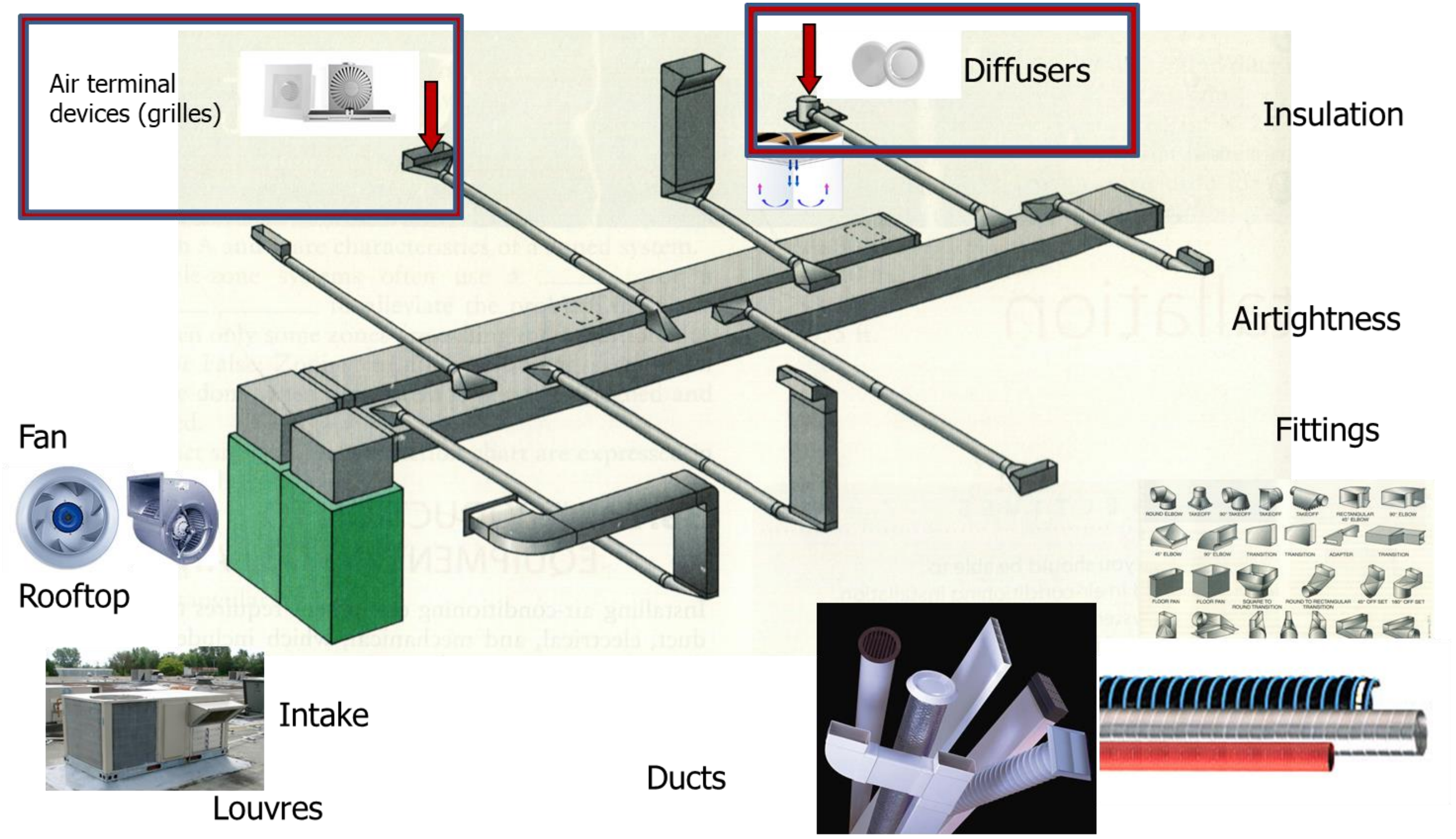
## *Air grilles, diffusers and filters*

*Renata Sikorska-Bączek*
*Dorota Skrzyniowska*

# OUTLINE OF LABORATORY EXERCISE:

- Definition of air grilles and diffusers
- Type of grilles and diffusers
- Air distribution
- Flow velocity – instruments used to mesure
- Air filters
- Function of air filters
- When to replace a dirty filter

# Air grilles and diffusers – parts of ventilation system



# Air grilles and diffusers

Air terminal devices for the ventilation of buildings and spaces in terms of supply

- grille – a special device used in supplying and extracting air vertically without any kind of deflection
- diffuser – a device used to direct the air at different angles by profiled blades when the air is leaving the unit and going into the space

# Materials

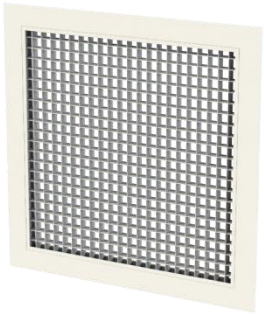
Air terminals are made of following materials

- aluminum
- mild steel
- stainless steel
- plastic

# Location

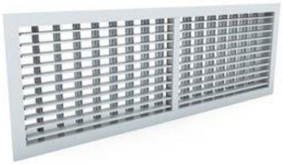
These devices are usually mounted in the floors, walls, doors, ceiling and in ducts. Some of these devices are specially designed for horizontal or vertical mounting. Floor devices are robust enough to withstand the pressure from foot traffic.

# Type of grilles – examples



Egg crate – These devices are considered to be the cheapest and the simpliest equipment of their category. The plenum box is visible above the equipment and can be seen from the room below. If the purpose is to remove air by extracting ventilation system then there is no need of the device having profiled blades to direct the air – so egg grate device can be used here.

- Bar type – This device's blades are shaped as a bar as opposed to a narrow blade. The bar is mostly of T shape which reduces the see through factor.
- Some linear bar devices come with angled or adjustable blades.



Transfer type – These devices are commonly used in the walls and doors for ventilation and also to stop the fire and smoke from spreading if in any case these occur. Sometimes transfer devices come with intumescent fire damper to act as insulation if fire erupts.

# Type of grilles – examples

Linear Bar Grille
Polymer Plenum Box
Linear bar grilles have a single row of horizontal blades

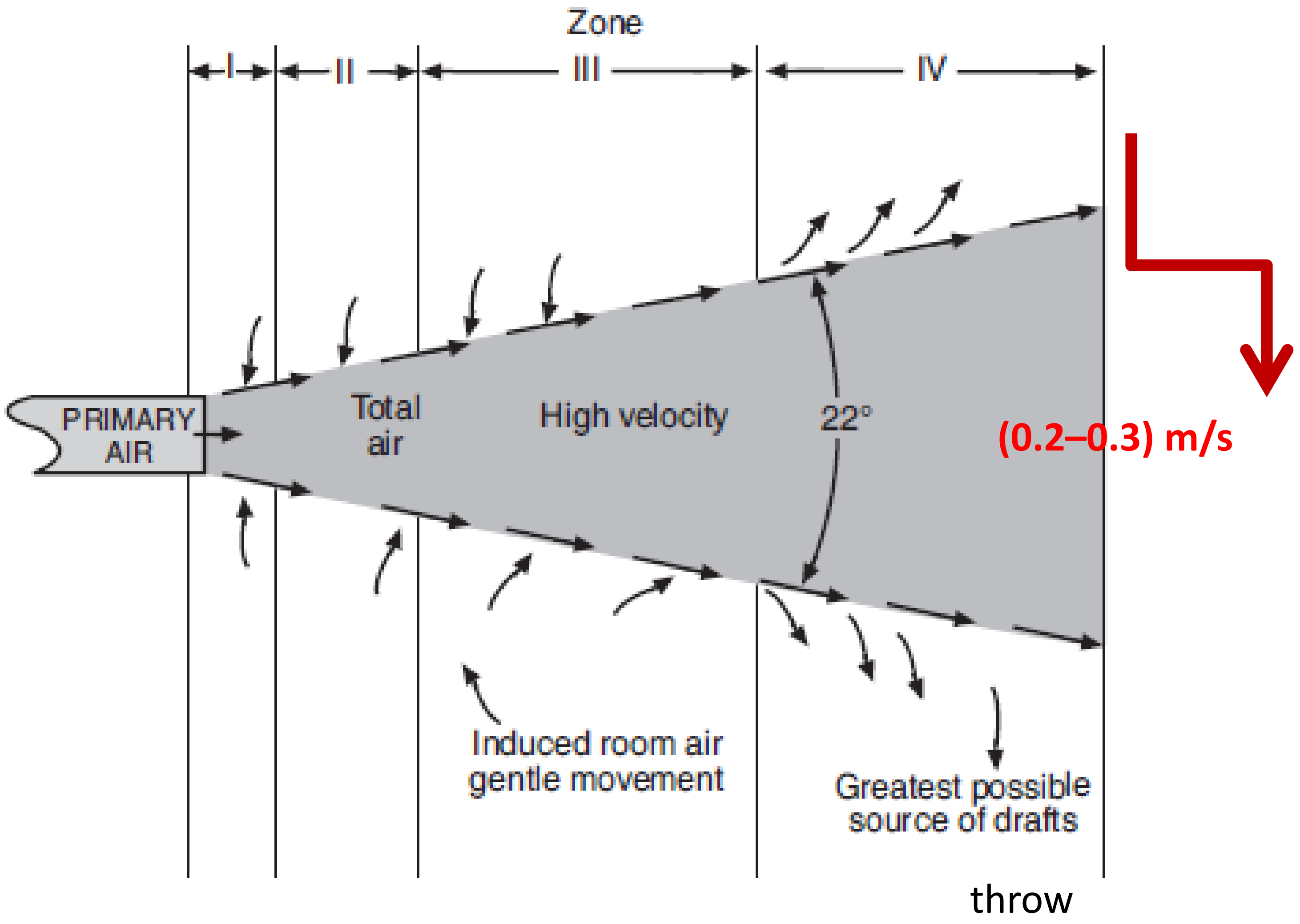
**Louver bladed device –** They supply air at the ceiling level and can be round and square in shape. Curved blades are capable of deflecting air in more than two directions which depends on the place at where it is located.

**Straight bladed –** Straight bladed devices are normally cheaper than louvre bladed devices and some of their types come with adjustable blades.

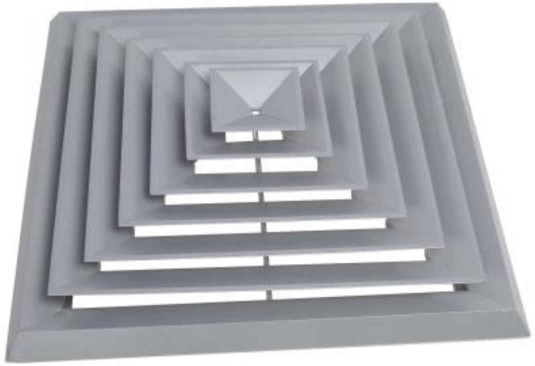
**Linear slot device –** Linear slot devices are used not only for distributing, but are also used for aesthetic purposes. They can be used for both the purposes of supplying or returning air. Blanking plates create dummy slots to produce a continuous linear effect.

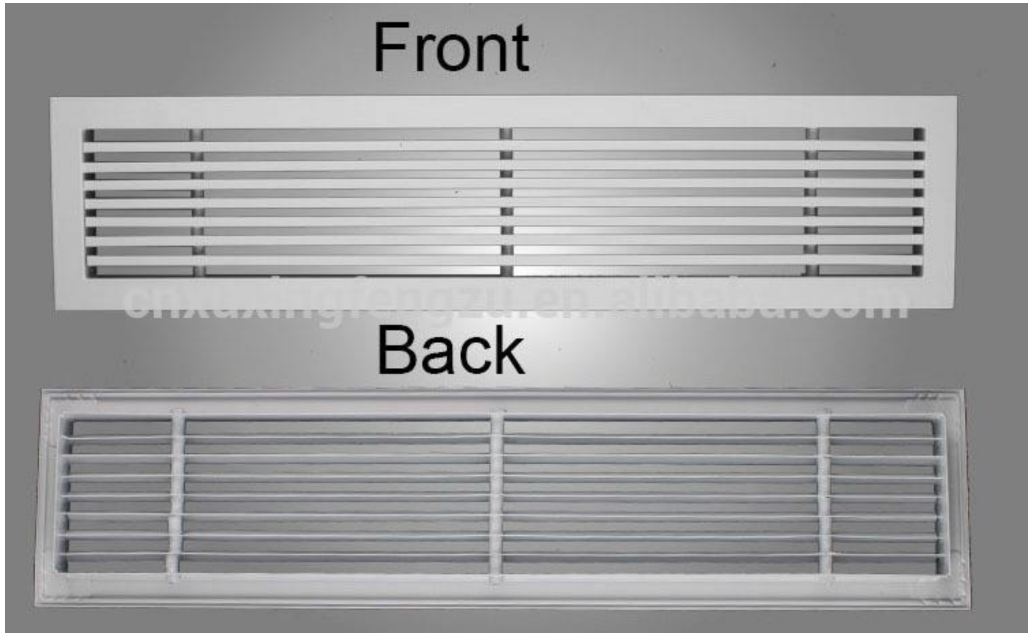
# Air distribution – expansion of primary air jet

Schematic free flowing – model of ideal jet isothermal air jet



# Type of grilles – examples





# Flow velocity

Flow velocity is an important factor when controlling air conditioning systems, ventilation systems and in many other areas.
Measurements can be made in open space, as well as in ventilation, air-conditioning and exhaust systems, and wherever the medium is being tested.
Flow rate / volume flow means the quantity of air that flows through a certain area (section) within one second.

# Instruments used to measure velocity – anemometer


**Fan**

**Measuring rod**


- An **anemometer** is a device used for measuring air stream velocity of air.

# Measuring Instruments: balometer

- **Air velocity**
- **Air volume**
- **Air pressure**

The types of instrumentation that can be used for the measurement and verification of various airflow parameters

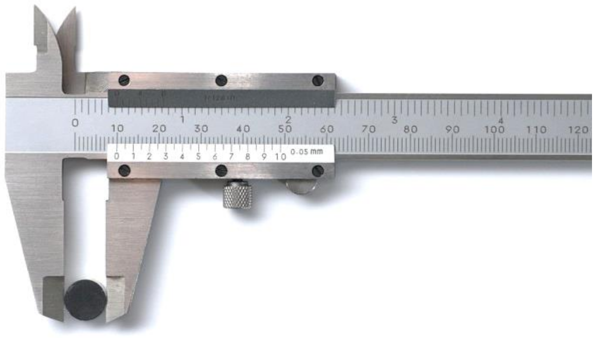

A **Balometer** is a device used for measuring the volume of air coming out of grilles and diffusers in HVAC systems. "**Balometer**" has become synonymous with "airflow capture hood" today.

*Source: balometer use*

# Instruments used to measure… – vernier caliper

**A vernier caliper –** is a device used to measure the distance between two opposite sides of an object. Many types of calipers permit reading out a measurement on a ruled scale, a dial, or a digital display.

The tips of the caliper are adjusted to fit across the points to be measured and then the caliper is then removed and the distance read by measuring between the tips with a measuring tool, such as a ruler.



# Air stream

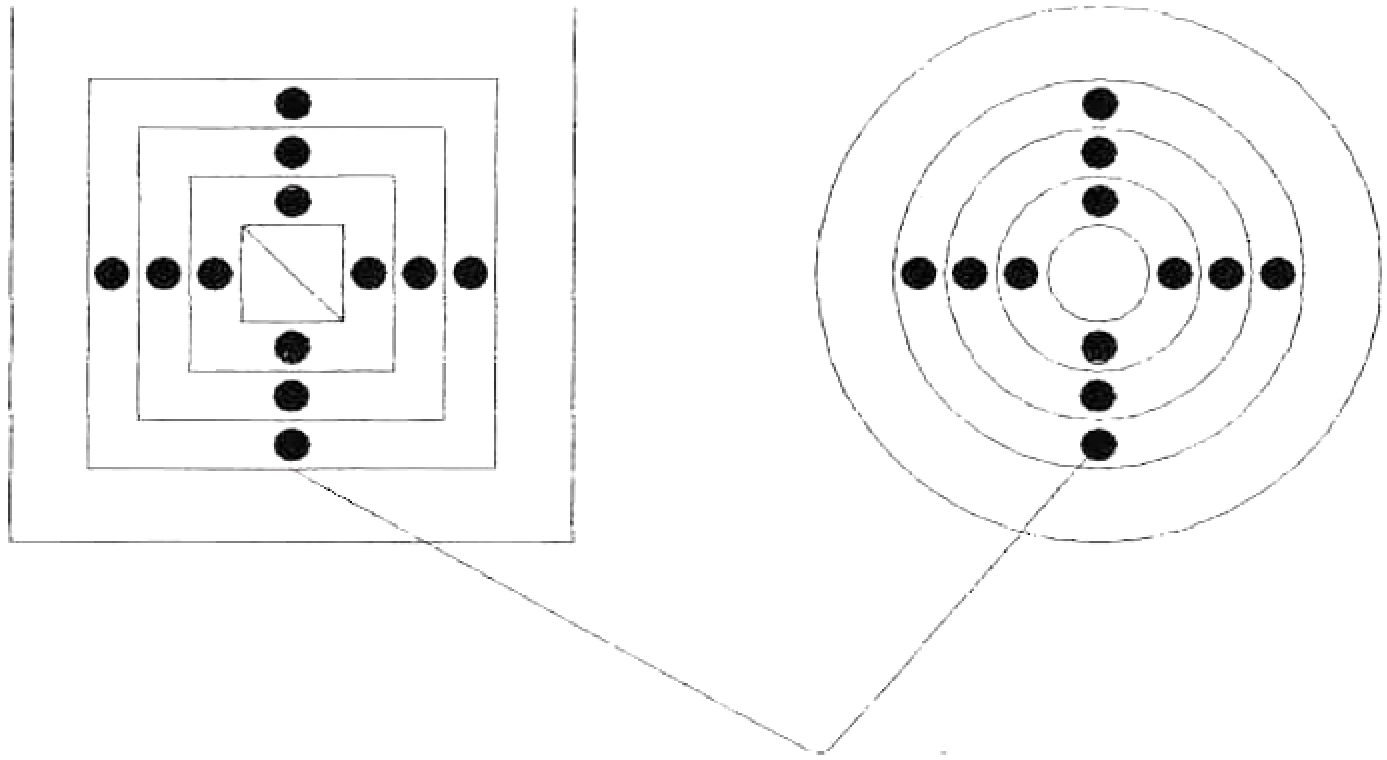
Air stream is calculated by measuring the velocity of air supply grill using an anemometer or a balometer and multiplying the velocity by the effective area of the grill.

# Effective area vs. free area

What are ***effective area*** and ***free area*** as they apply to grilles, registers and diffusers? What are the differences between these two areas and how are they used in our industry?

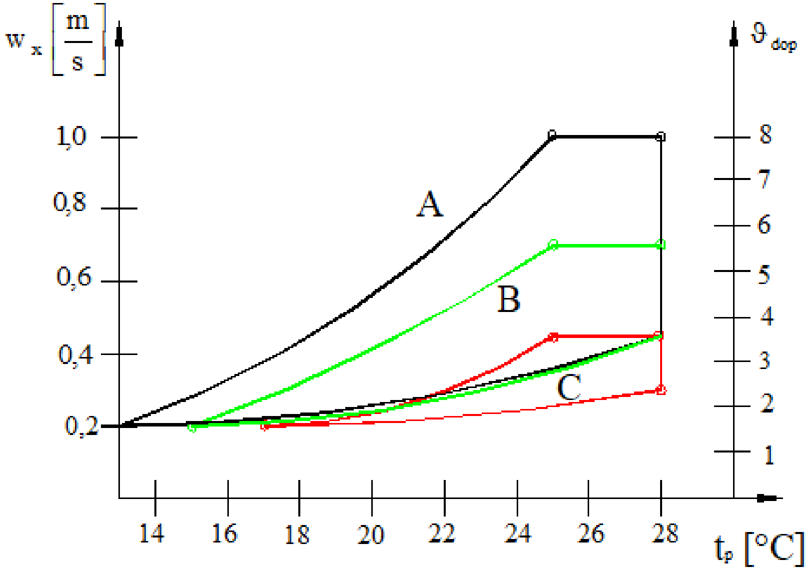
**Effective area**, given the abbreviation Ak (pronounced "A sub k"), is the area of the register, grille, or diffuser in square feet that is utilized by the air flowing through it.

# Where to measure?



# Indices of thermal comfort

$$\Delta_x = \Delta t_x + 8w_x$$




| | | |
|---|---|---|
| $u_x$ | - | effective draft temperature [-] |
| $\Delta t$ | - | difference between ambient air temperature in the human residence zone and air temperature at a distance of x from the grill, [K] |
| wx | - | velocity of air at a distance of x [m/s] |

# The function of air filters

An air filter is usually made of a spun fiberglass material or cloth enclosed in a cardboard frame. It’s basic function is to clean the air that circulates through HVAC systems. Filters trap and hold many types of particulates and contaminants that could affect health and comfort, including:

- Dust and dirt
- Pollen
- Mold and mold spores
- Fibers and lint
- Metal, plaster or wood particles
- Hair and animal fur
- Bacteria and microorganisms

# Why replace a dirty filter?

- dirty filters can damage heating and cooling equipment
- can reduce the airflow inside the HVAC system, which can cause air-handling fans to work harder and wear out quicker
- can’t remove particulates and contaminants effectively, which allows these materials back into the indoor air
- can cause contaminants to accumulate in HVAC system ductwork
- can cause HVAC equipment to work harder, increasing energy usage and unnecessarily driving up monthly energy bills

# When should a dirty filter be replaced?

High pressure drop on a filter – the best moment to replace dirty filters

$$p_{dynamic} = \frac{\rho\, v^2}{2} \quad [\mathrm{Pa}]$$

where:

$p_{dynamic}$ – dynamic pressure [Pa]
$v$ – air flow velocity [m/s]
P – air density in temperature 20°C , $\rho = 1.2\ kg/m^3$

# Mathematically, when to replace a dirty filter

High pressure drop on a filter – the best moment to replace dirty filter

Solving that equation for air flow velocity gives:

$$v == \sqrt[2]{\frac{2\,p_{dynamic}}{\rho}} \approx 1.3\sqrt[2]{p_{dynamic}}\ \text{[m/s]}$$

Volumetric flow of air flowing through the duct is estimated from equation:

$$V = v_a\ F\ [m^3/s],[m^3/h] \qquad (3)$$

Where:

v – air velocity [m/s]

F – duct surface [$m^2$]

# Measuring the pressure drop on a clean filter according to air flow function

| Fan speed | Pressure drop on filter | Dynamic pressure in duct | Air velocity in duct | Air flow in duct | Air flow in duct |
|---|---|---|---|---|---|
| % | [Pa] | [Pa] | [m/s] | [$m^3/s$] | [$m^3/h$] |
| 100 | | | | | |
| 90 | | | | | |
| 80 | | | | | |
| 70 | | | | | |
| 60 | | | | | |
| 50 | | | | | |
| 40 | | | | | |
| 30 | | | | | |
| 20 | | | | | |
| 10 | | | | | |

# Measuring the pressure drop on a dirty filter according to flow function

| Fan speed | Pressure drop on filter | Dynamic pressure in duct | Air velocity in duct | Air flow in duct | Air flow in duct |
|---|---|---|---|---|---|
| % | [Pa] | [Pa] | [m/s] | [$m^3$/s] | [$m^3$/h] |
| 100 | | | | | |
| 90 | | | | | |
| 80 | | | | | |
| 70 | | | | | |
| 60 | | | | | |
| 50 | | | | | |
| 40 | | | | | |
| 30 | | | | | |
| 20 | | | | | |
| 10 | | | | | |

# Laboratory exercise 3

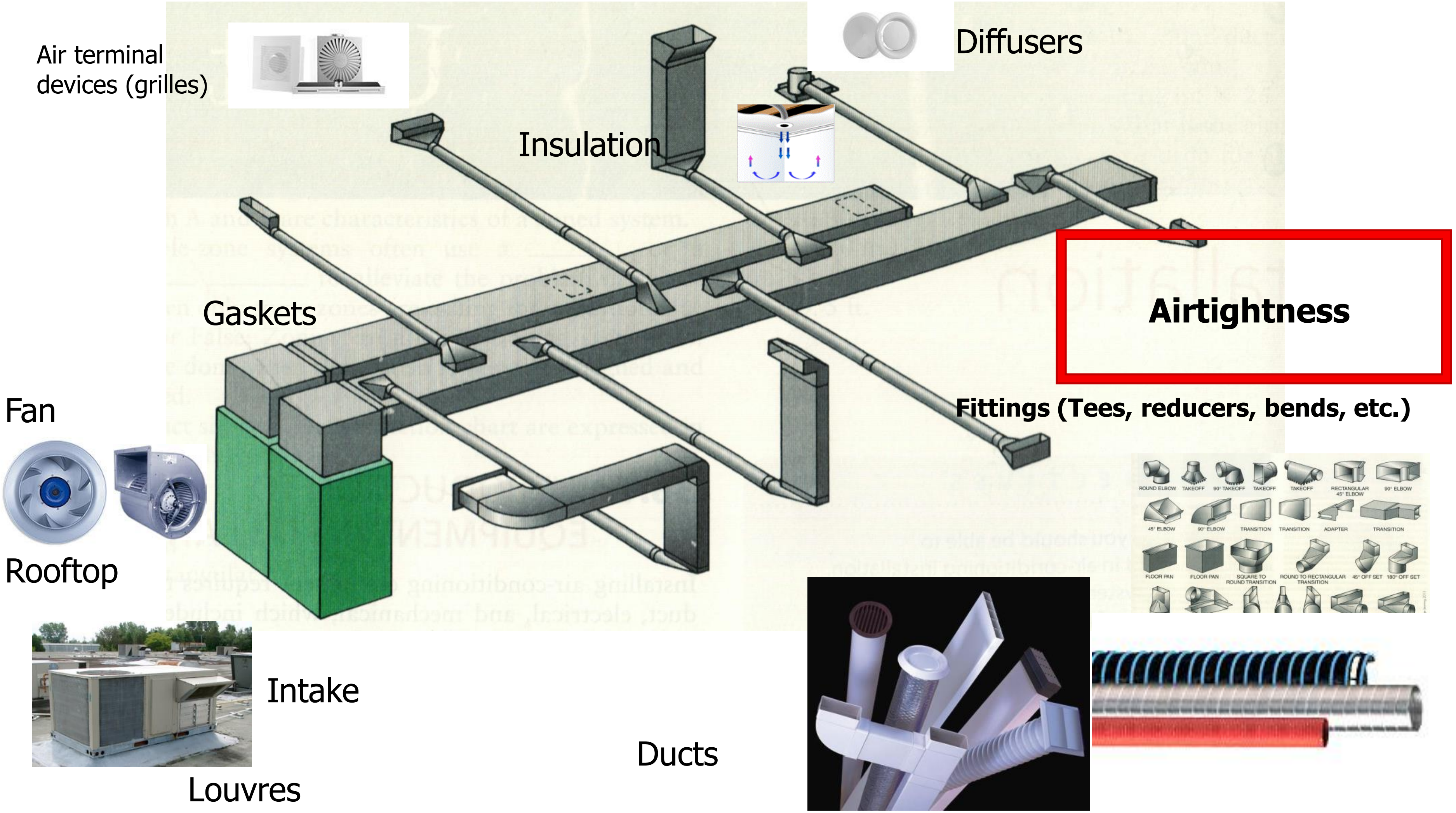
# *Ductwork airtightness*

*Renata Sikorska-Bączek*
*Dorota Skrzyniowska*

# OUTLINE OF LABORATORY EXERCISE:

- Air tightness in mechanical ventilation installations
- Lasses of air tightness
- Ductwork airtightness
- Duct leakage tester
- The sources of leaks in ventilation
- Inspection on leak testing of ventilation ducts

# Tightness – resistance leakage



# Air tightness in mechanical ventilation installations

When selecting ventilation ducts, designers should take into account:

- their diameter
- the material they are made from
- and air tightness

# Classes of airtightness

The designer should indicate the optimal way to connect the ventilation ducts, so that they maintain tightness according to the indicated tightness class.

We have 4 classes of tightness. A,B C D.

D is the best class.

Proper ventilation of the building requires only following solutions that guarantee tightness.

# Ductwork airtightness

Ductwork airtightness – the resistance to inward or outward air leakage through the ductwork envelope.

This air leakage is driven by differential pressures across the ductwork envelope due to the combined effects of stack and fan operation.

# Elements of ductwork system

Ductwork:

- ducts
- fittings (tees, reducers, bends, etc.) that are used to supply the air to or extract the air from the conditioned spaces.

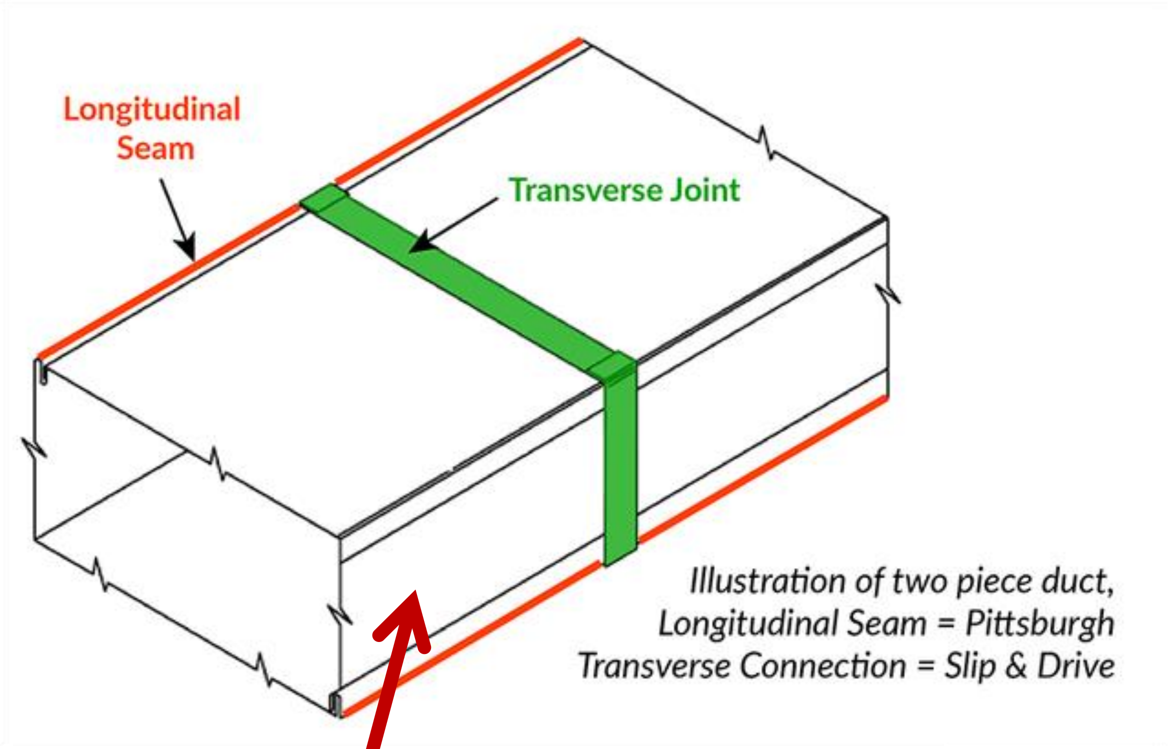
# Duct leakage tester

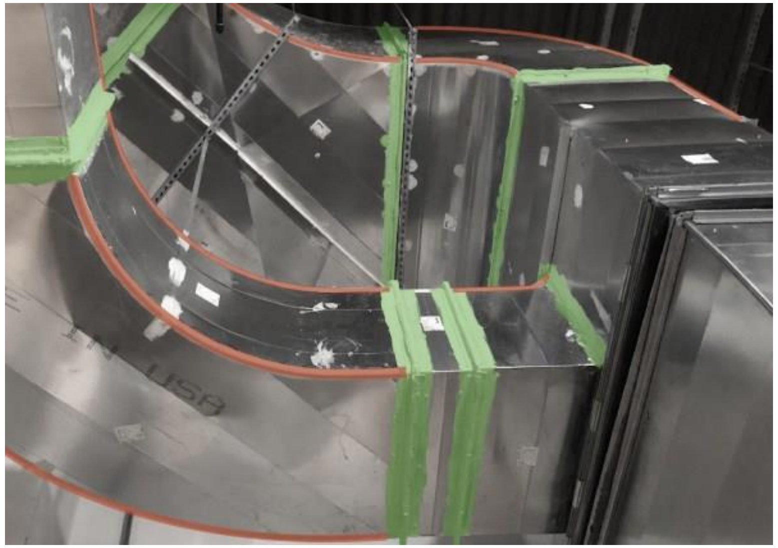
Ductwork airtightness is the fundamental ductwork property that impacts the uncontrolled leakage of air through duct leaks.
It is important to minimise leakage in the system.

# What affects the leak tightness

- The tightness of ventilation ducts determines the efficiency of the installation (less heat loss and greater comfort of use).
- Energy consumption increases, according to the principle that the larger amount of air to be treated – the more work for ventilation devices.
- Lot of risks, including the condensation of water and probability of developing microorganisms in the ducts.

# The sources of leaks in ventilation



- longitudinal, transverse joints and fittings of ducts
- inspection and cleaning doors, ventilation grilles and diffusers

# Inspection and leak testing of ventilation ducts – action plan

1. Measurement of air velocity in the supply duct (by Prandtl tube) and then calculation of the supply of air flow (rational speed of fans 100%):

$$V_{duct} = w\ A_{duct}\ \ [m^3/h]$$

2. Identification of diffusers and grills based on the manufacture's catalog (FRAPOL). Reading the effective surface of the diffusers and grills ($A_{ef}$) from catalog listings.
3. Measurement of air flow velocity from diffusers and grills by anemometer.

# Inspection and leak testing of ventilation ducts – action plan

4. Calculation of the air stream flowing out from the individual diffusers and grills:

$$V_n = A_{ef} \, w_{ef} \; [m^3/s],[m^3/h]$$

where:

$w_{ef}$ – average air velocity[m/s]
$A_{ef}$ – effective surface [$m^2$]

# Inspection and leak testing of ventilation ducts – action plan

5. Air balance in the room:

$$V_{duct} = \sum_{n=1}^{6} V_n$$

where:

$V_{duct}$ – air stream flowing through the supply duct [$m^3/h$]
$\sum V_n$ – total of air steams flowing from all grills and diffusers [$m^3/h$]

6. Visualization of air flow from diffusers and grills in the room through the smoke distribution

# Laboratory exercise 4

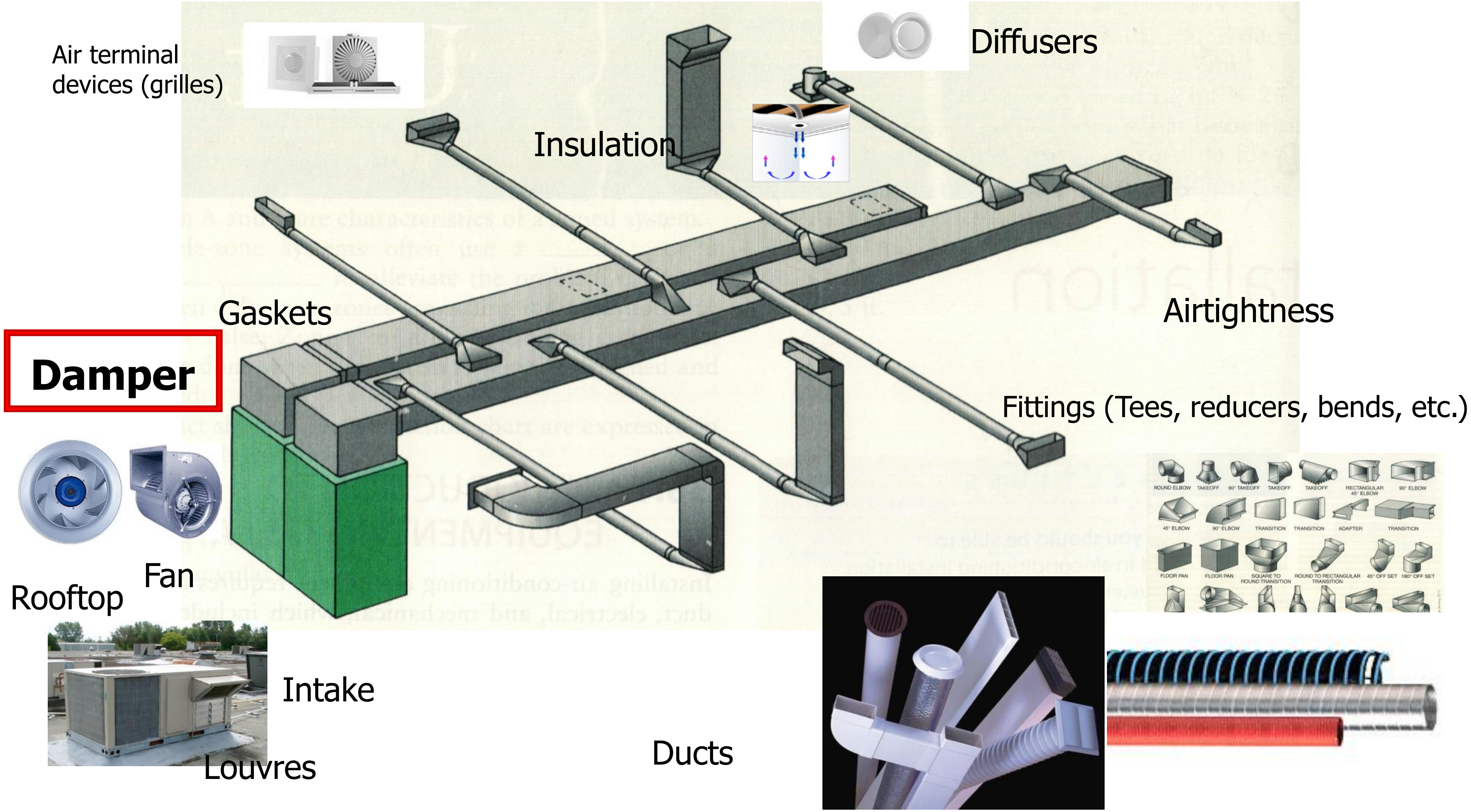
# *Damper – airtightness*

*Renata Sikorska-Bączek*
*Dorota Skrzyniowska*

# OUTLINE OF LABORATORY EXERCISE:

- Damper definition
- Types of dampers
- Damper – airtightness
- Damper's classification by leakage class

# Damper


Air terminal devices (grilles)
Diffusers
Insulation
Gaskets
Airtightness
Damper
Fittings (Tees, reducers, bends, etc.)
Fan
Rooftop
Intake
Louvres
Ducts

# Damper

Damper – a mechanical device, a valve or plate that stops or regulates the flow of air inside a duct or chimney, Variable Air Volume (VAV) box, air handler, or other air handling equipment.

# Regulating damper

Zone damper

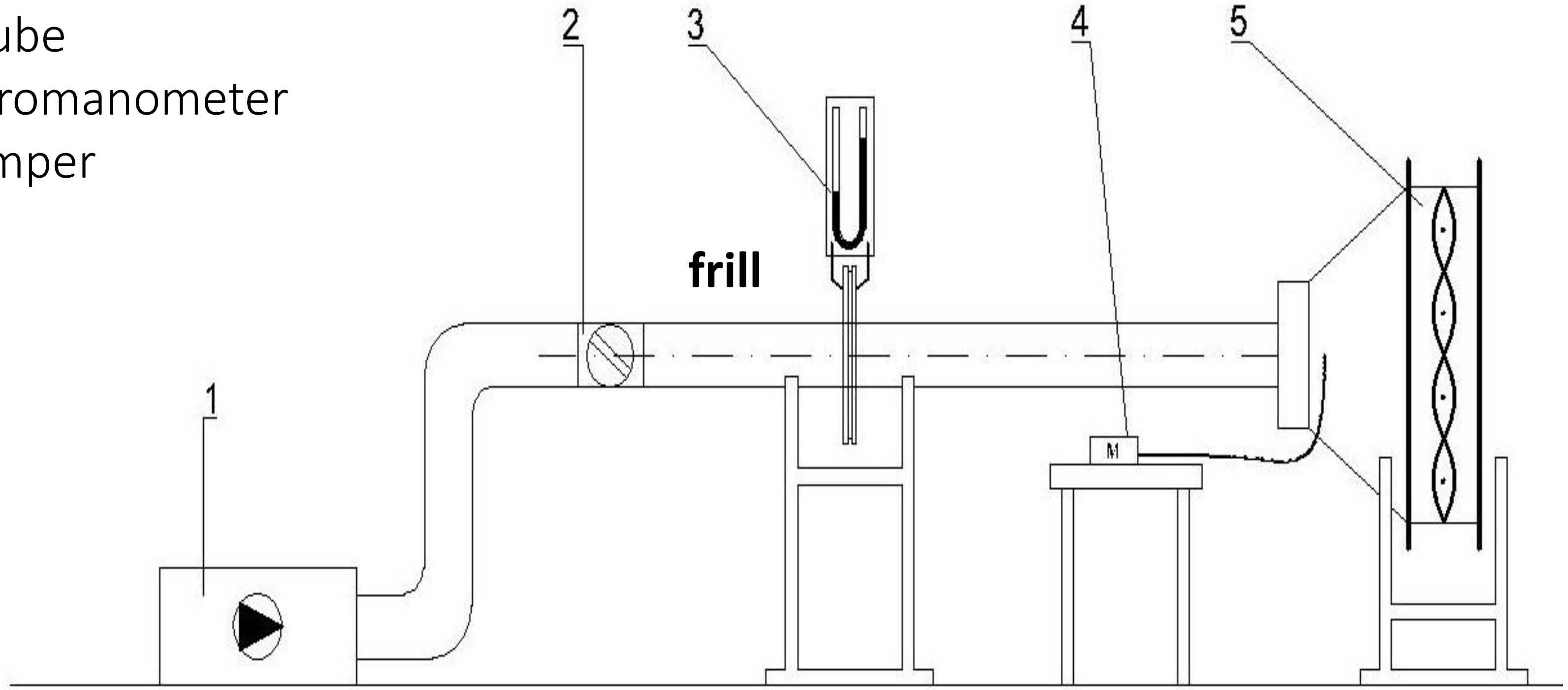
*Source: zonedampers.com*

# Regulating damper

Airfoil control damper (blade)

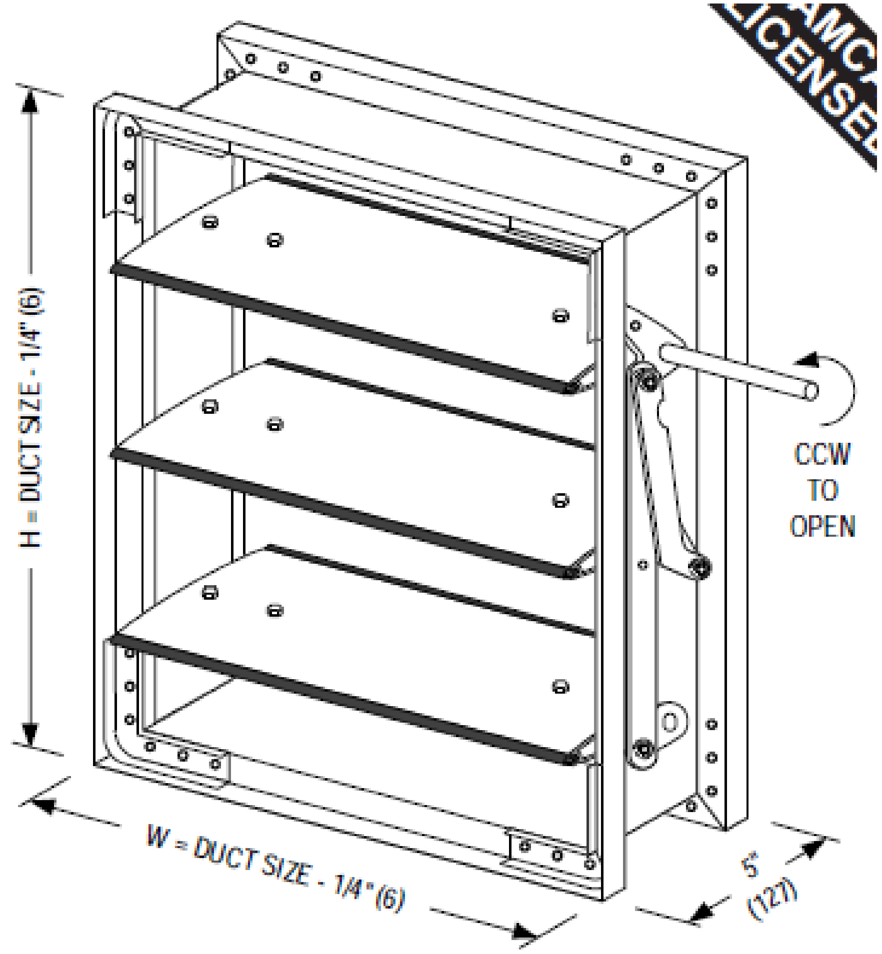
# Damper – airtightness

1 – fan
2 – bypass valve
3 – U-tube
4 – micromanometer
5 – damper

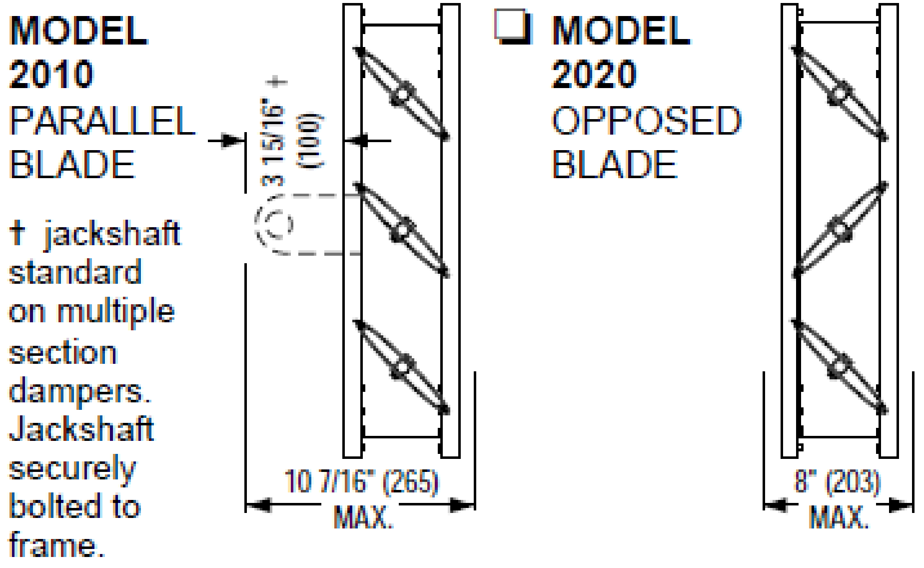


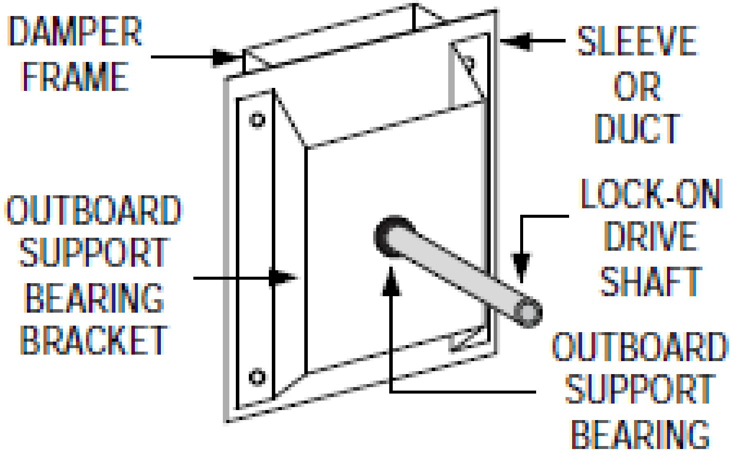

Test bed (laboratory set up)

# Damper – airtightness




Source: *nailorproduct/catalog/NailorCatalog*



# Calculating leakage air flow rate through a closed damper

$q_v = q_m/\rho$ – volume flow rate [m³/s]

$q_m = \frac{C}{\sqrt{1-\beta^4}} * \varepsilon\pi * \frac{D_k^2}{4} * \sqrt{2\Delta p\rho}$: mass flow rate [kg/s],

$\varepsilon = 1 - 0.295\frac{\Delta p}{p_i} = 1 - 0.295\Delta p * 10^{-5}$ : expansion number

$$p_1 = p_{otoczenia} - p_{1pom} \cong 10^5 \text{ [Pa]}$$

$$\rho \cong 1.2 \left[\frac{\text{kg}}{\text{m}^3}\right]$$

# Calculating leakage air flow rate through a closed damper

$c = 0.6151$ : flow rate

$D_k = 0.015\ [\mathrm{m}]$: diameter of venturi (reducers)

$D = 0.052\ [\mathrm{m}]$: diameter of duct

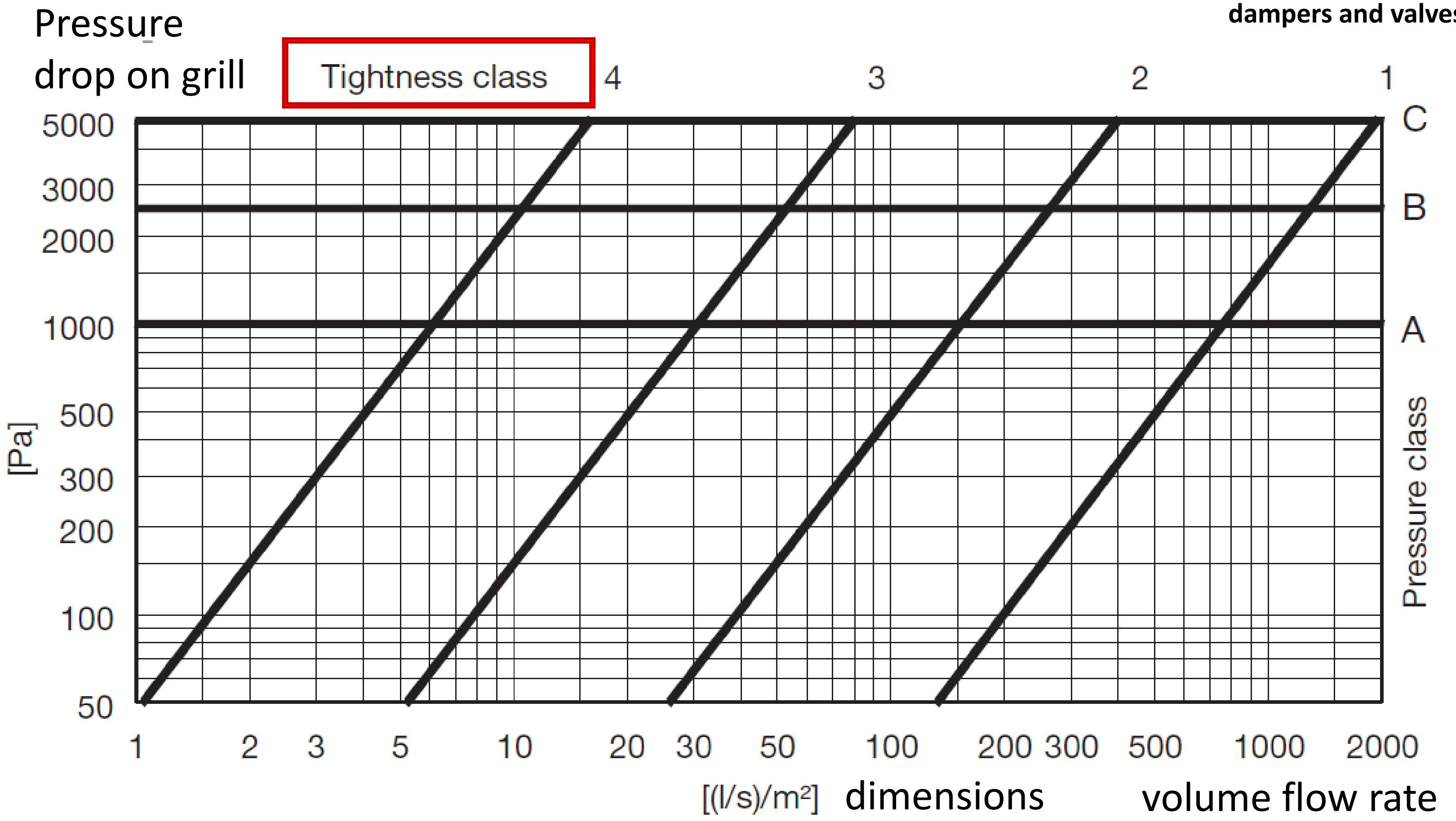
$\beta = \frac{D_k}{D}$ : necking of venturi

$\Delta p$ : differential pressure [Pa]

$\rho_{alk} = 1000\ \left[\frac{\mathrm{kg}}{\mathrm{m}^3}\right]$: density of water.

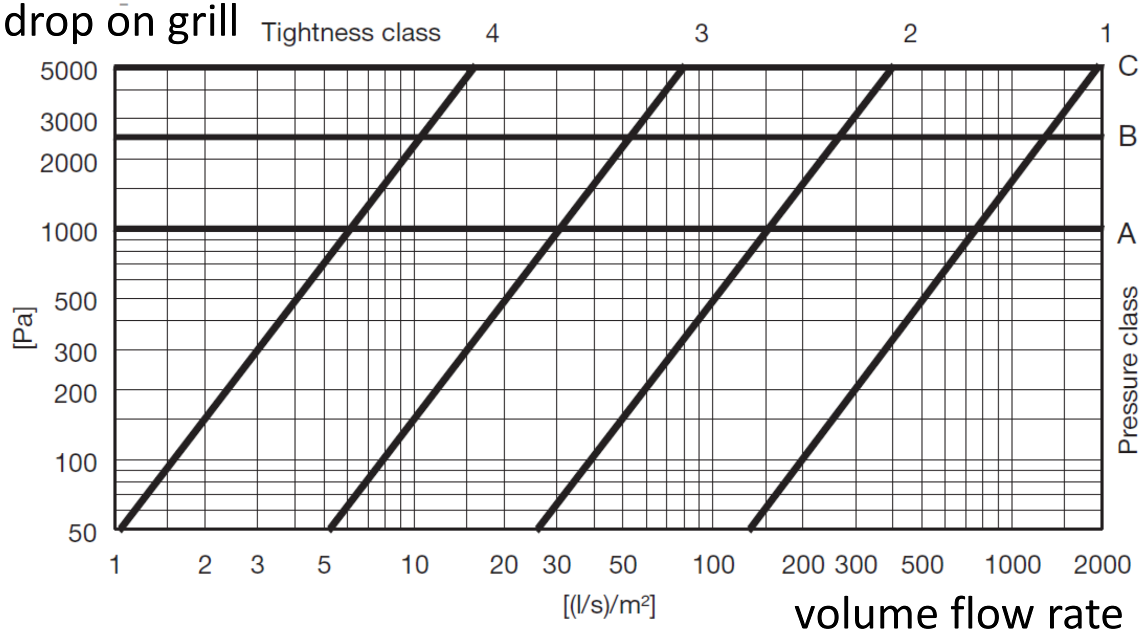
# Classification by leakage class

**BS EN 1751:1999**
**Ventilation for buildings. Air terminal devices. Aerodynamic testing of dampers and valves**

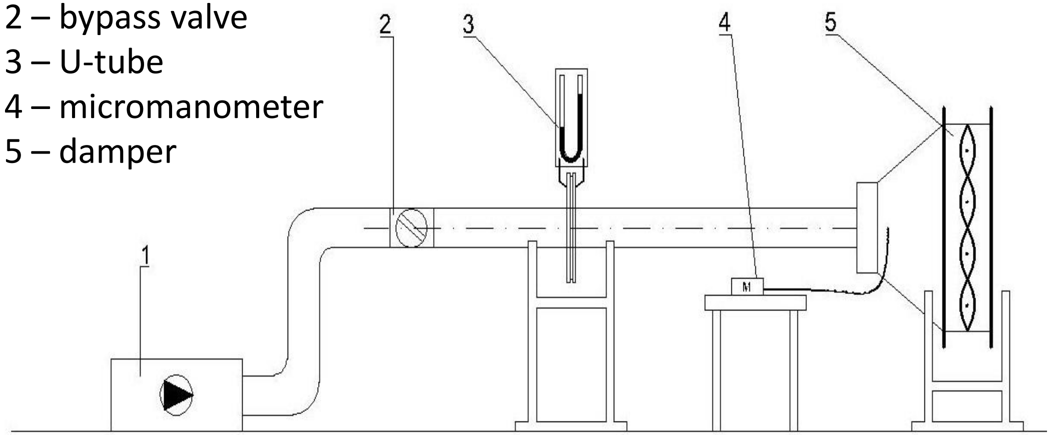


# Classification by leakage class

Pressure
drop on grill



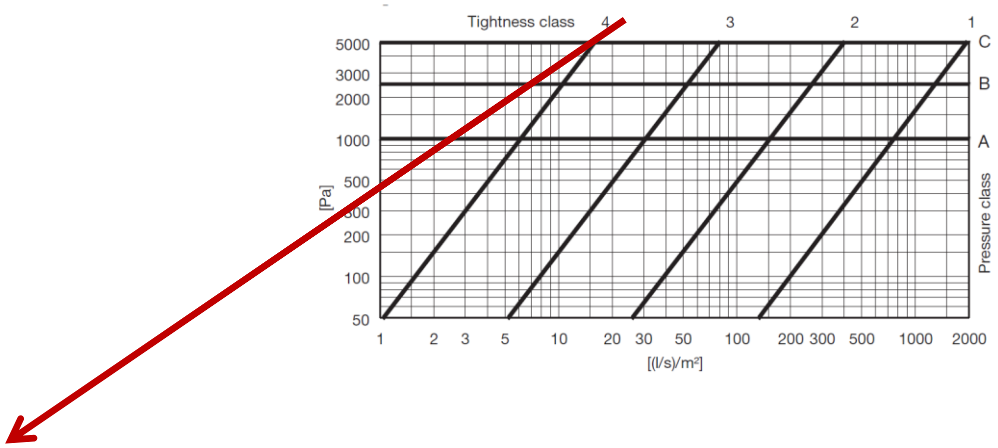

1 – fan
2 – bypass valve
3 – U-tube
4 – micromanometer
5 – damper



# Measurement and calculation results

| Pressure in the duct-line (Dp imposed on the damper) | U-the tube | | Differential pressure gauge | | Dp | Expansion number | mass flow rate | volumetric flow rate |
|---|---|---|---|---|---|---|---|---|
| | h | Dp = rgh | Dp | Dp | $Dp_{śr}$ | e | $q_m$ | $q_V$ |
| Unit → | [m] | [Pa] | [mBa] | [Pa] | [Pa] | [-] | [kg/s] | [m3/s] |
| 50 | | | | | | | | |
| 100 | | | | | | | | |
| 200 | | | | | | | | |
| 500 | | | | | | | | |
| 1000 | | | | | | | | |

# Damper – class of airtightness


The damper is of ………… class of airtightness.

# Laboratory exercise 5

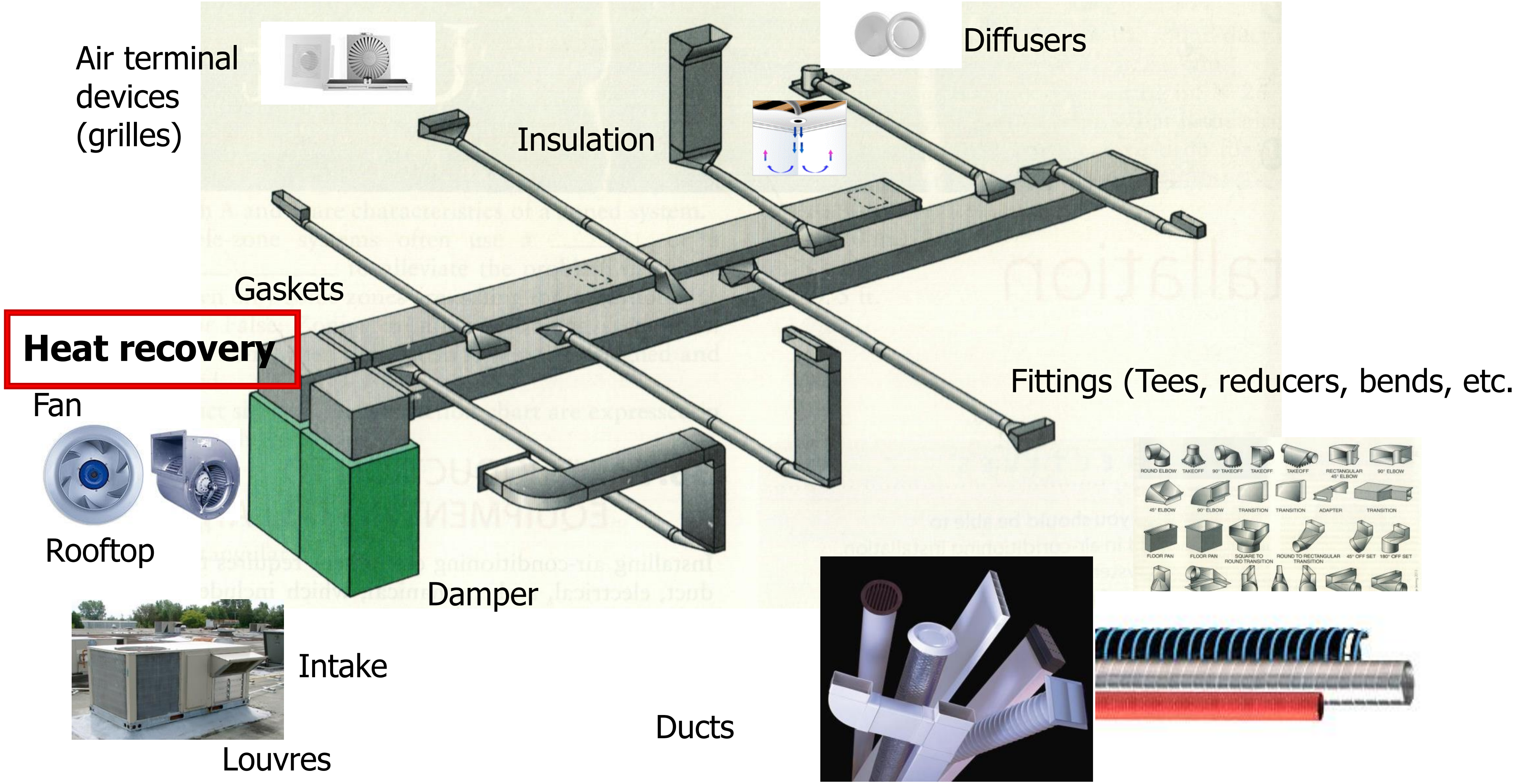
## *Heat recovery*

*Renata Sikorska-Bączek*
*Dorota Skrzyniowska*

# OUTLINE OF LABORATORY EXERCISE:

- Heat recovery definition
- Benefits of heat recovery
- Heat recovery systems
- Efficiency of heat recovery

# Heat recovery



# Heat recovery

**Heat recovery systems**

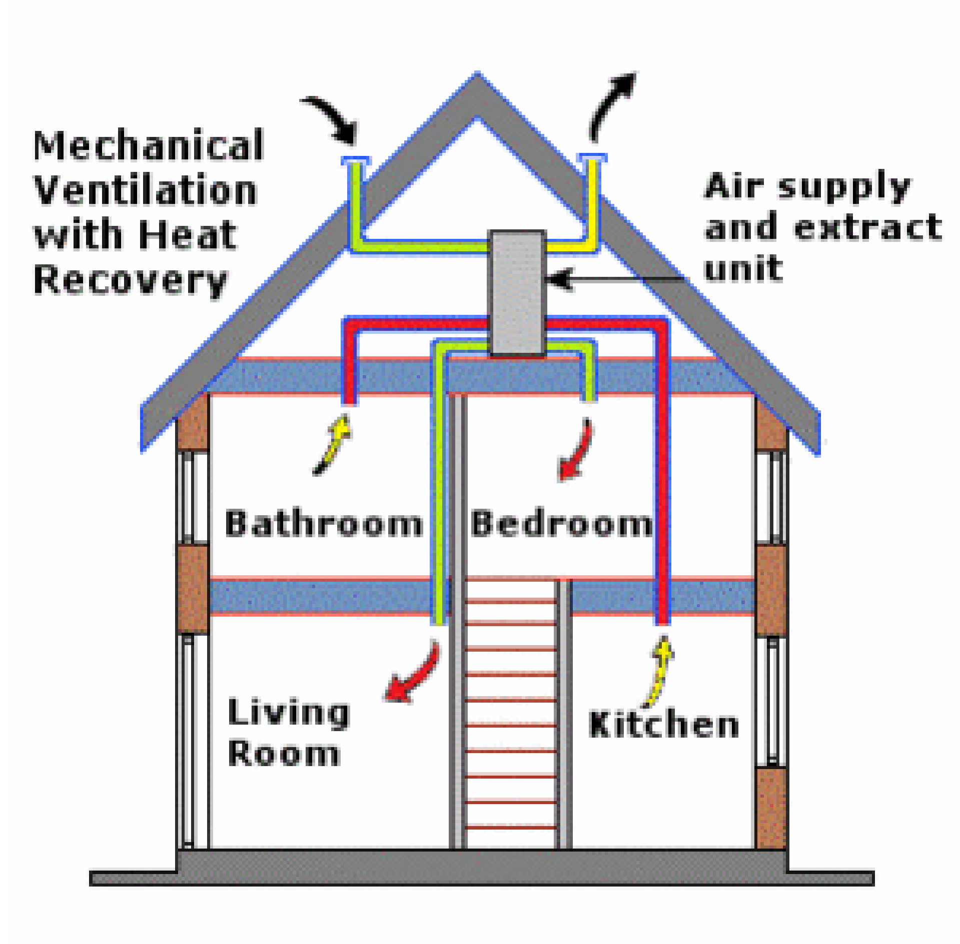
are designed to use the heat in the air being extracted from the building to heat fresh air being drawn into the building.

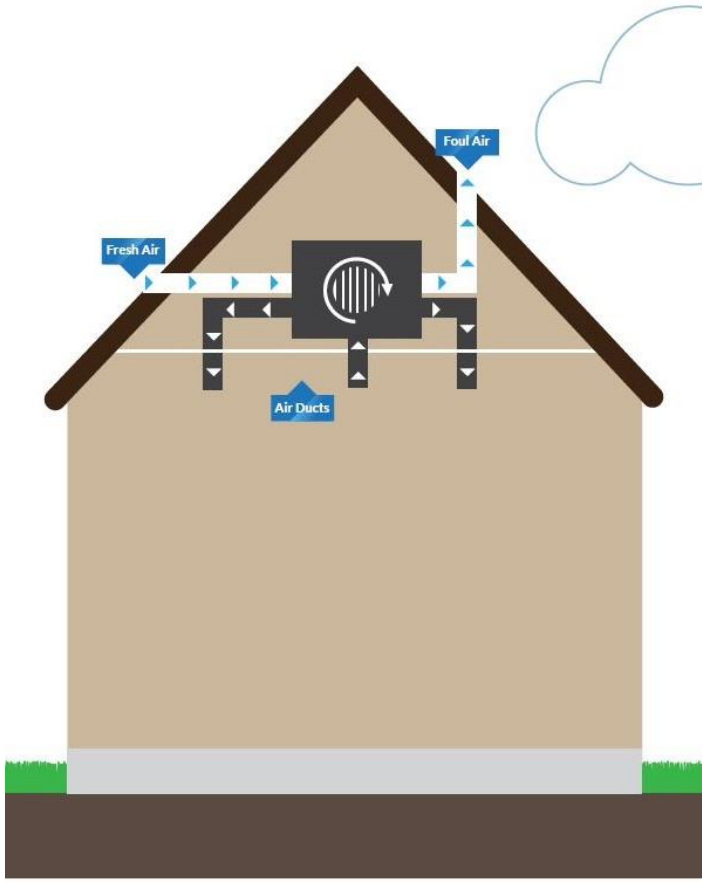
# Heat recovery – benefits

**Benefits:**

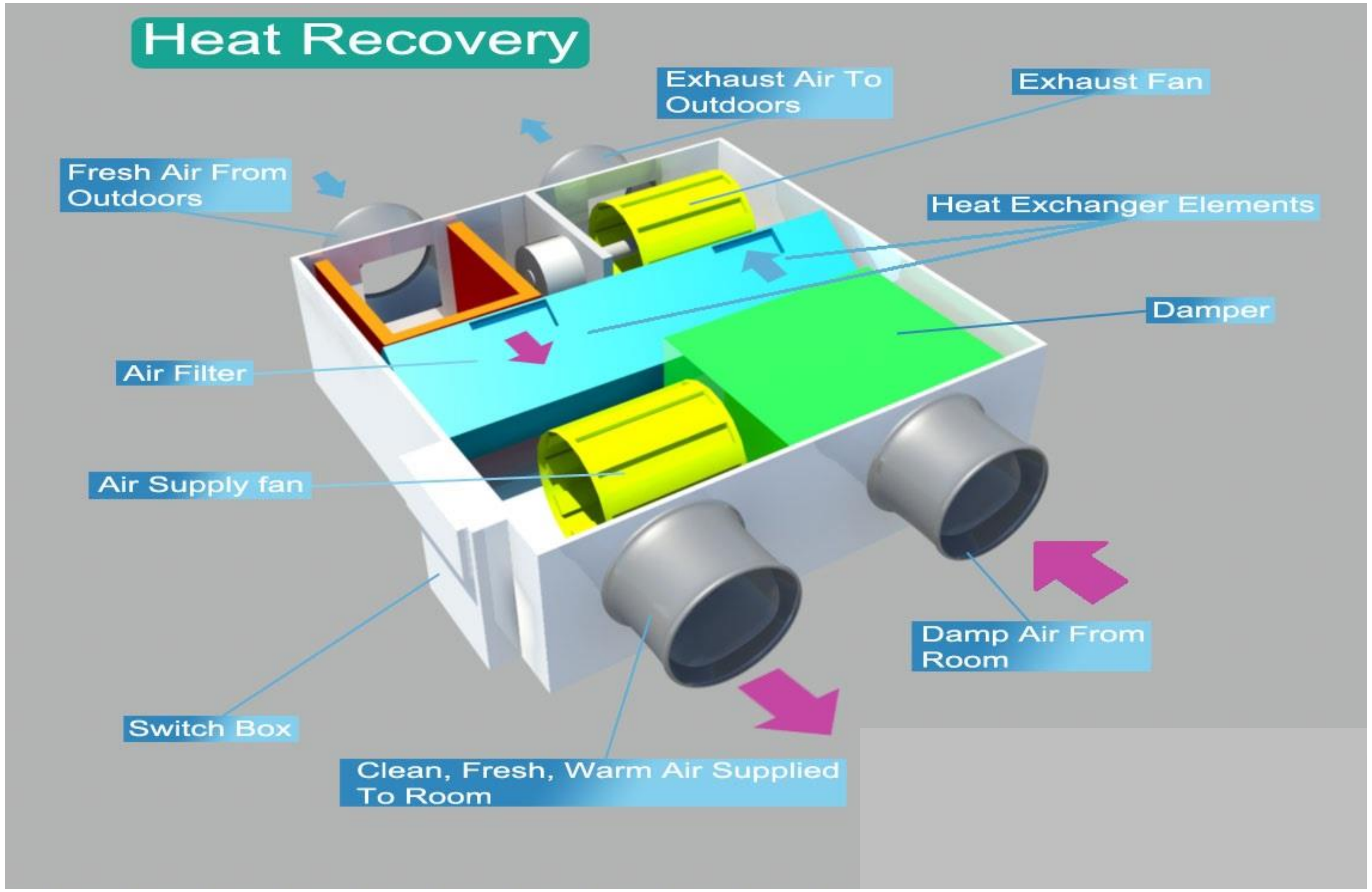
- cost savings
- quiet operation
- reduces heat loss from uncontrolled ventilation
- filtered fresh air improves air quality for asthma and hay-fever sufferers

# Heat recovery



# How do heat recovery systems work?

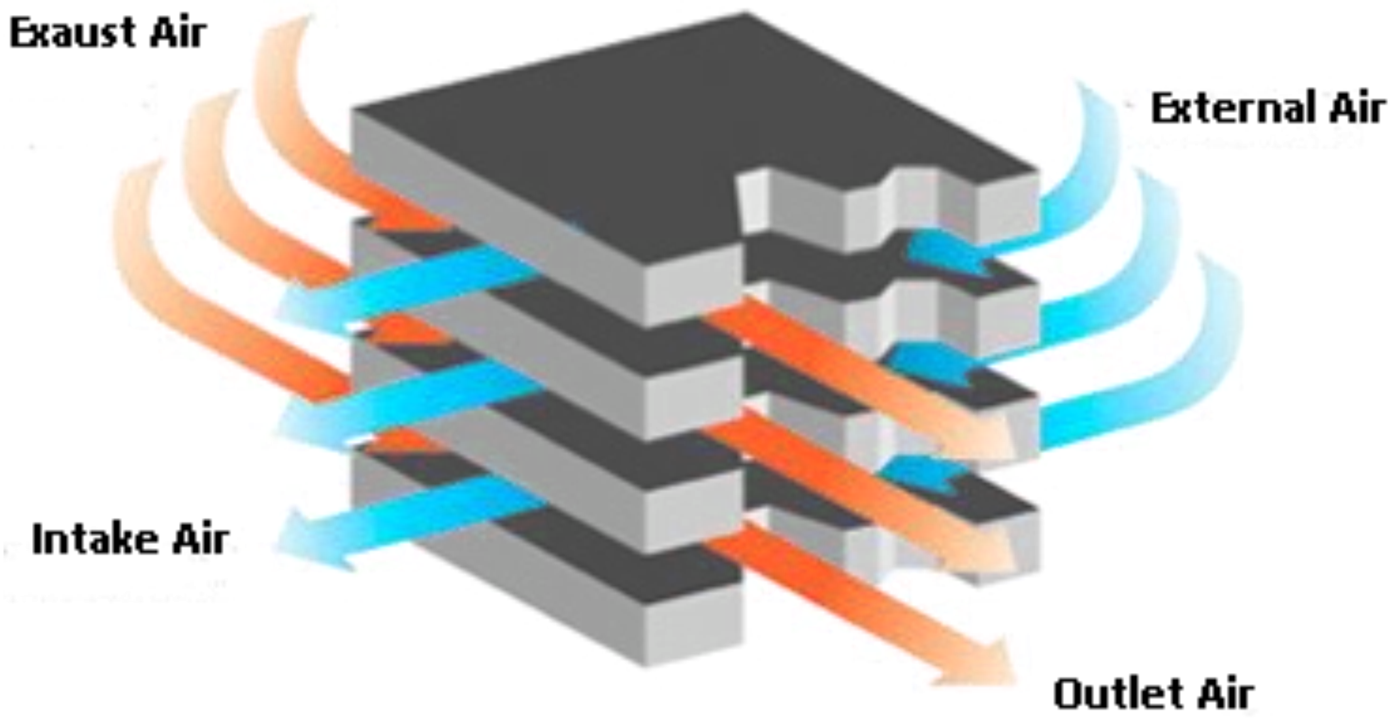



*Source: renewableenergy*

# Heat exchanger – process

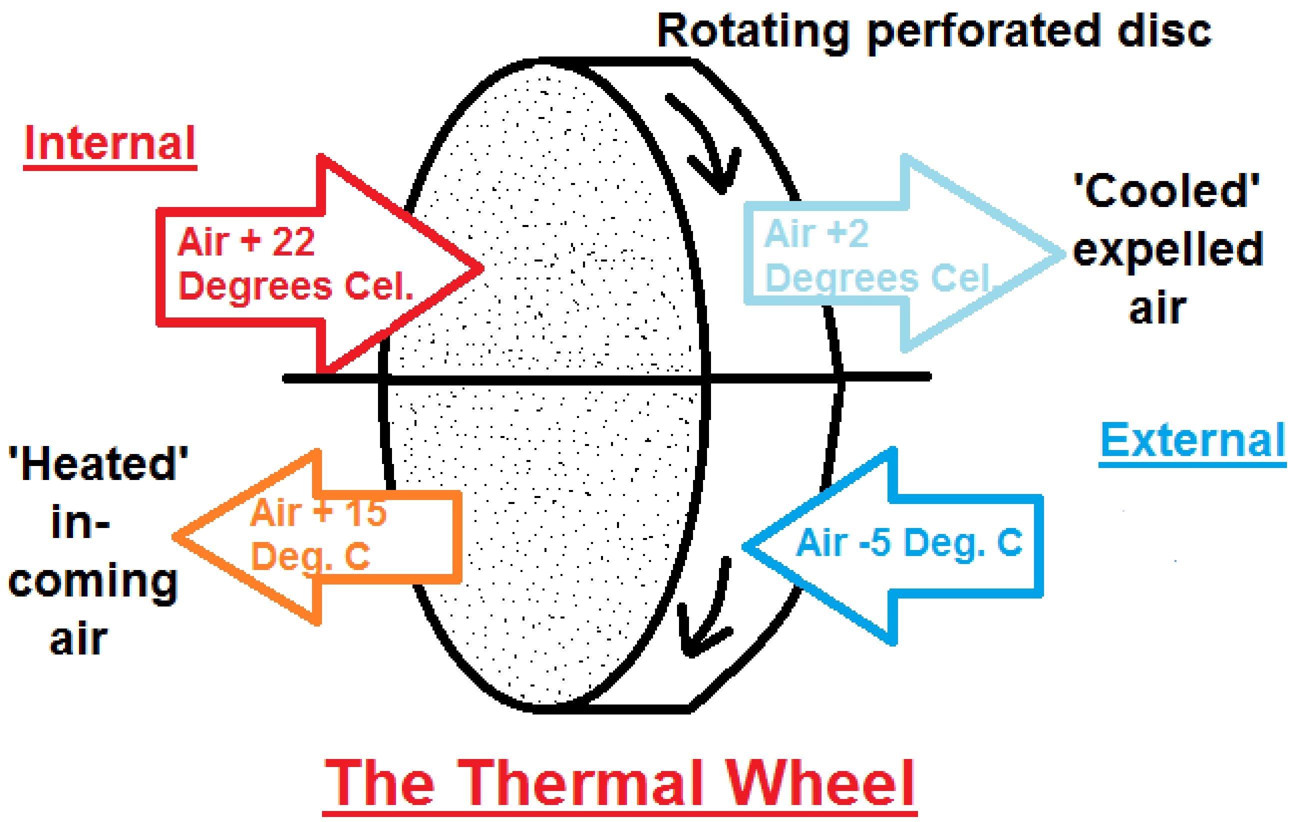
**Heat exchanger** – is a **device** used to transfer heat between two or more fluids.
Heat exchangers are used in both cooling and heating processes.
Fresh air is brought into the property heat exchanger, passes though the heat exchanger and picks up the heat recovered from the stale air.
The warmed fresh air is then ducted to all of the habitable rooms within the building.

# Plate heat or recuperator technology – heat exchanger




*Source: renewableenergyhub.co.uk/main/heat-recovery-systems-information/types-of-heat-recovery-system/*

# The thermal wheel – rotary heat echanger




*Source: thehelpfulengineer.com*

# Heat flow, heat transfer

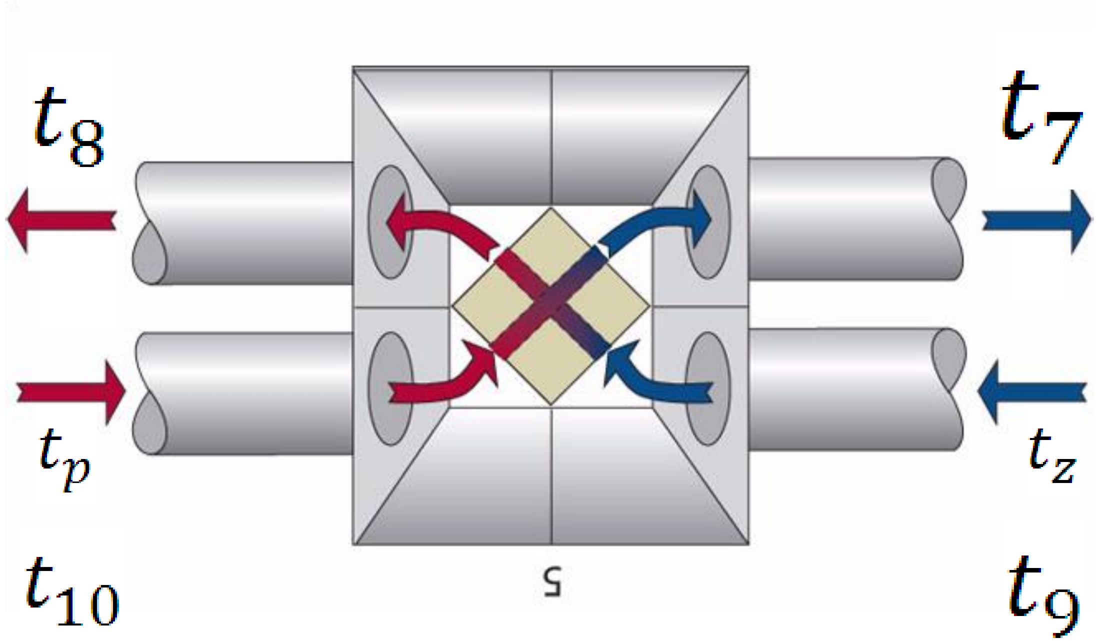
## Sensible heat (on account of difference temperature)

## Latent heat (moisture recovery)

Heat and moisture exchange:
**Heat recovery** – when intake air and outlet air  are separated by a solid wall to prevent mixing or they may be in direct contact
**Regeneration** – when intake air and outlet air flow one after the other

# Efficiency of heat recovery

## Sensible heat




$$\eta = \frac{t_8 - t_9}{t_{10} - t_9}$$

# Laboratory exercise 6

## *Testing different faucet attachments*

*Joanna Bąk*

# OUTLINE OF LABORATORY EXERCISE:

- Introduction
- Basic definition
- Flow rate of faucets
- Types of stream

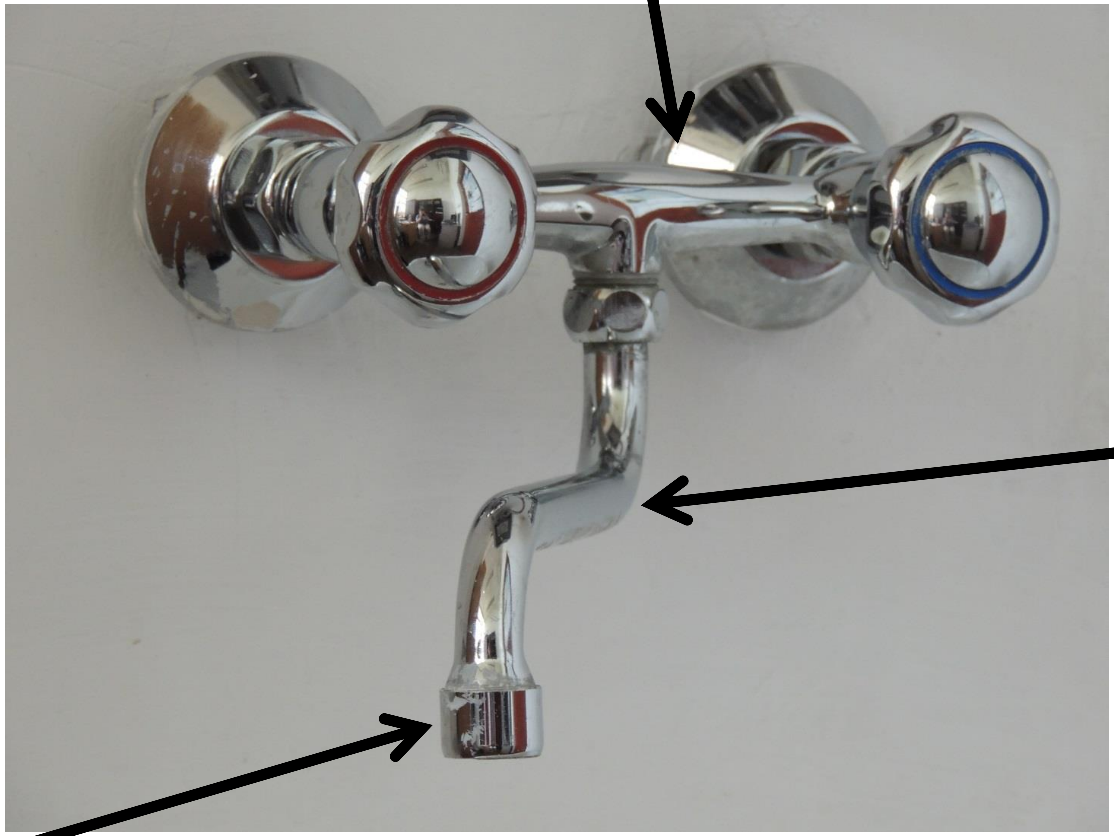
# Introduction

- what is the outflow from the washbasin faucet?
- what types of stream pattern do you know?
- which flow rate is suitable for public lavatories and which for domestic use?

# Faucets

- Control the cold and hot water supply
- Classified as:
  - ✓ COMPRESSION FAUCETS (TWO-HANDLE MIXER)
  - ✓ PORT CONTROL FAUCETS (SINGLE-HANDLE FAUCETS)

Faucet body



Swing spout

End of spout – faucet attachment: aerator or/and flow regulator/restrictor

The picture presents the basic elements of a wall – hung compression faucet.

# Different types of thread

Male M24x1 (external thread)


*Source: sklep.pge.com.pl/perlator-pca-spray-3-8-m24x1-itr-p-199.html*

Female M22x1 (internal thread)

*Source: sklep.pge.com.pl/perlator-pca-spray-1-9-lmin-m22x1-slc-p-140.html*

# EN 246 Sanitary tapware – General specifications for flow rate regulators

## Norm defines the flow rate classes at 3 bar pressure as shown in the table

| Flow rate class | Flow rate range per l/min | Dynamic pressure |
|---|---|---|
| Z | 7.5–9.0 l/m | 3 bar |
| A | 13.5–15.0 l/m | 3 bar |
| S | 18.0–19.8 l/m | 3 bar |
| B | 22.8–25.2 l/m | 3 bar |
| C | 27.0–30.0 l/m | 3 bar |
| D | 34.8–37.8 l/m | 3 bar |

*Source: neoperl.ch/en/retail/products/aerators/standards/europeanstandards.html*

# Stream patterns

AERATED

SPRAY

LAMINAR

MIKADO

RAIN

*Source: neoperl.ch/en/retail/products/aerators/stream.html*

Aerators introduce air into the water stream to produce a larger and whiter stream that is soft to the touch and non-splashing. Aerators are the usual choice for residential faucet applications.

Laminar stream straighteners produce a non-aerated water stream. Ideal for high-flow applications or health care facilities (no mix of water/air). This spout-end devices deliver a crystal-clear and non--splashing stream.

The use of a non-aerated stream is very important solution for hospital and other health facilities due to mitigation of the risk of Legionella infection.

*Source: neoperl.ch/en/retail/products/aerators/stream.html*

When the flow rate is too low to produce an aerated or laminar stream, a spray device is used to produce a miniature shower pattern to provide full coverage of the hands during washing. Sprays are recommended for use in public lavatories.

Rain Spray offers a special washing experience. Numerous little nozzles join forces to produce an extensive, abundant and pleasantly effervescent stream of water – a shower sensation for your hands.

*Source: neoperl.ch/en/retail/products/aerators/stream.html*

The unique Mikado stream turns the water into an eye--catcher when washing your hands. Its extraordinary, grid-like spray pattern – formed by individual water jets – makes for a clear, delicate and harmonious design.

*Source: neoperl.ch/en/retail/products/aerators/stream.html*

# Research program

1) Choose a faucet attachment and write its number in the table
2) Recognize the type of stream
3) Select the filling time of the beaker (5 or 10 seconds)
4) Fill the beaker within 5/10 seconds **three times**
5) Measure the volume of water in the beaker (using a measuring cylinder)
6) Calculate the flow rate (the outflow from the faucet)
7) Change the end spout to another one

# Laboratory report

## Complete the table

| Number of end spout | Faucet attachment | Type of stream | Time [s] | Volume [ml] | Flow rate [l/s] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |

# Answer the questions

- compare the results and choose the best end spout for public toilets and household use
- count how much money you can save using low-flow devices
- how many times do you wash your hands during one day?
- how much time does it take?
- what is the difference between standard end spout and low – flow devices (in l/s)?

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dla-niepelnosprawnych-zasady-projektowania-wymiary-wymogi.html

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EN 246 Sanitary tapware – General specifications for flow rate regulators.

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EN 13779 Ventilation for non-residential buildings – Performance requirements for ventilation and room--conditioning systems.

EN 13829 Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method.

EN 15239 Ventilation for buildings. Energy performance of buildings. Guidelines for inspection of ventilation systems.

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eISBN 978-83-66531-29-1